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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

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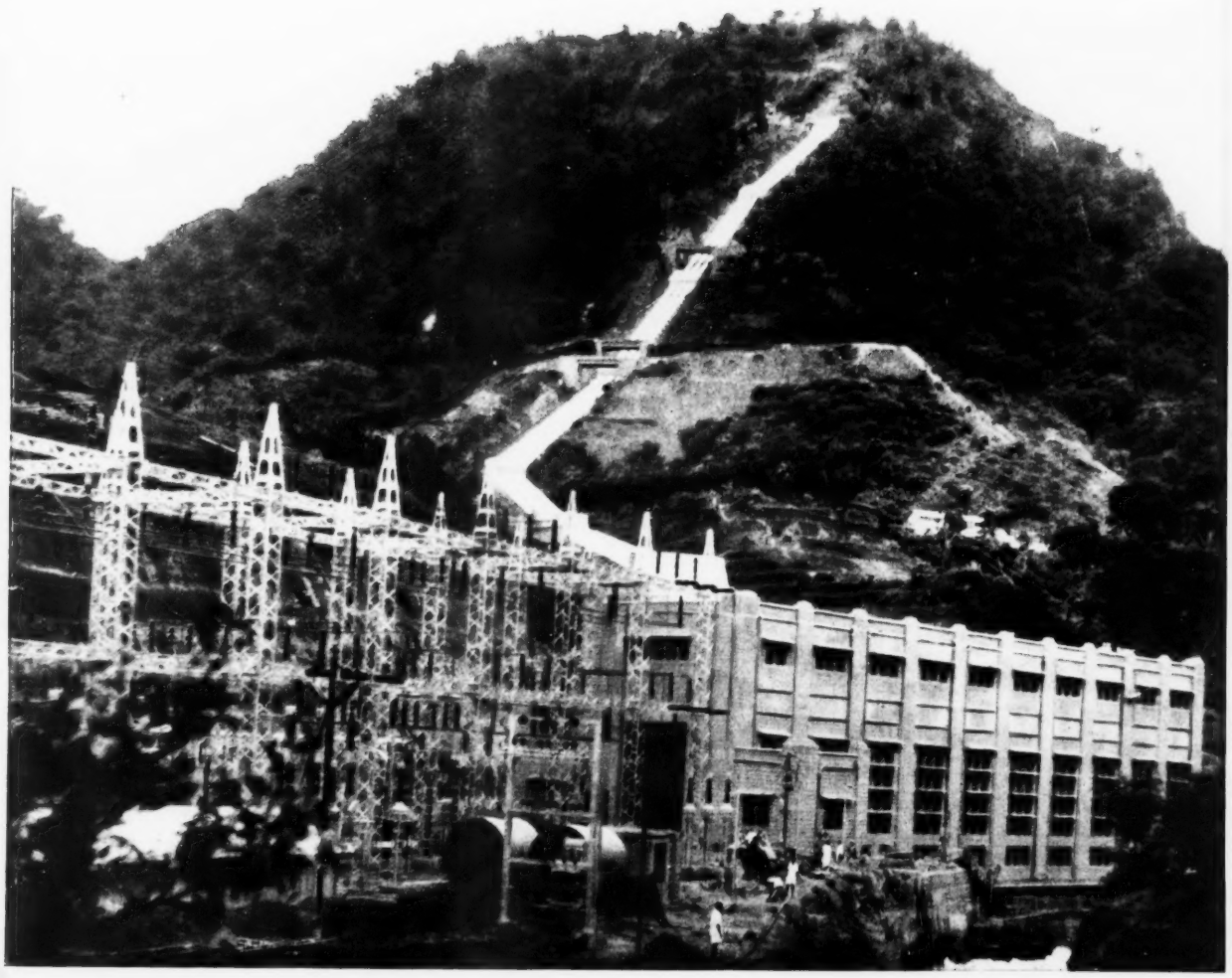
VOL. VIII. NO. 9 SEPTEMBER, 1958 RUPEES THREE



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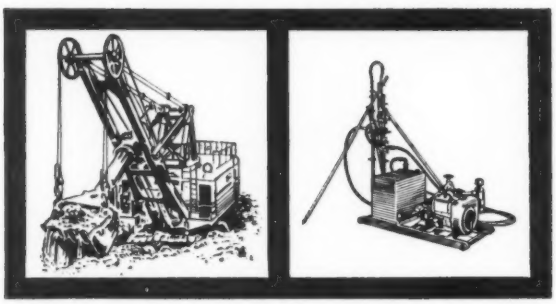
These machines make it possible to provide new soil for the uprooted, new homes for destitutes.



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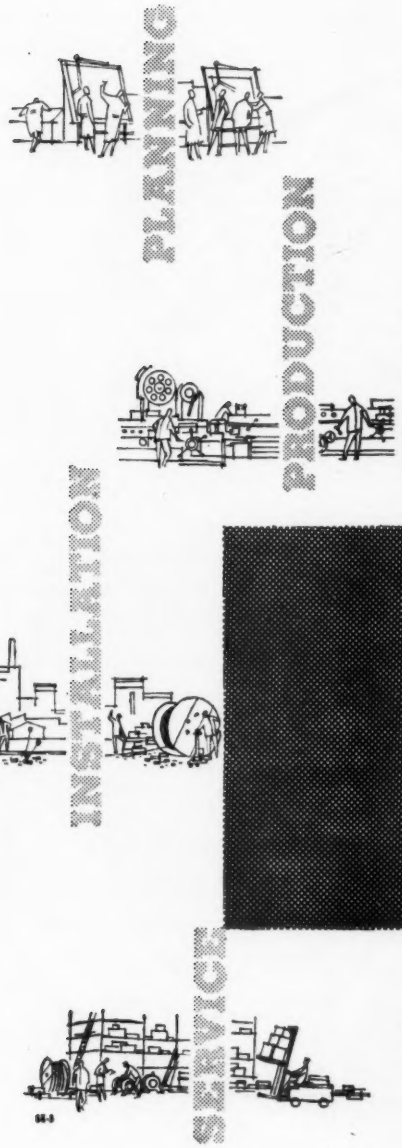

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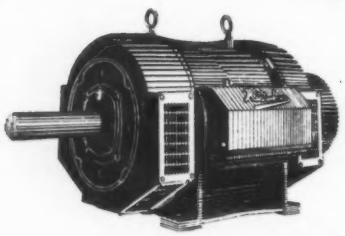

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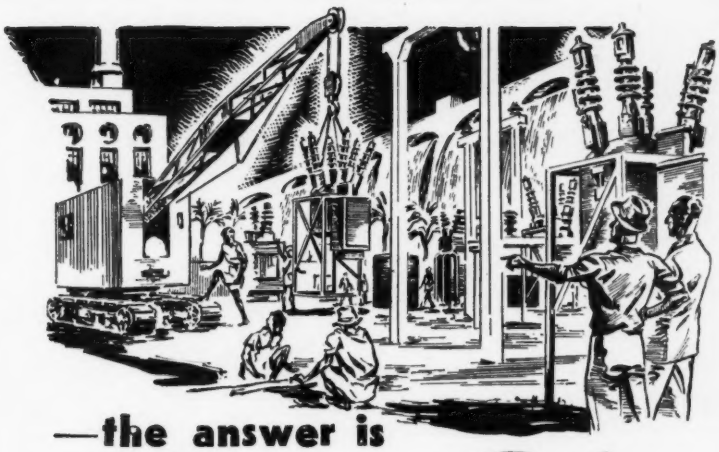
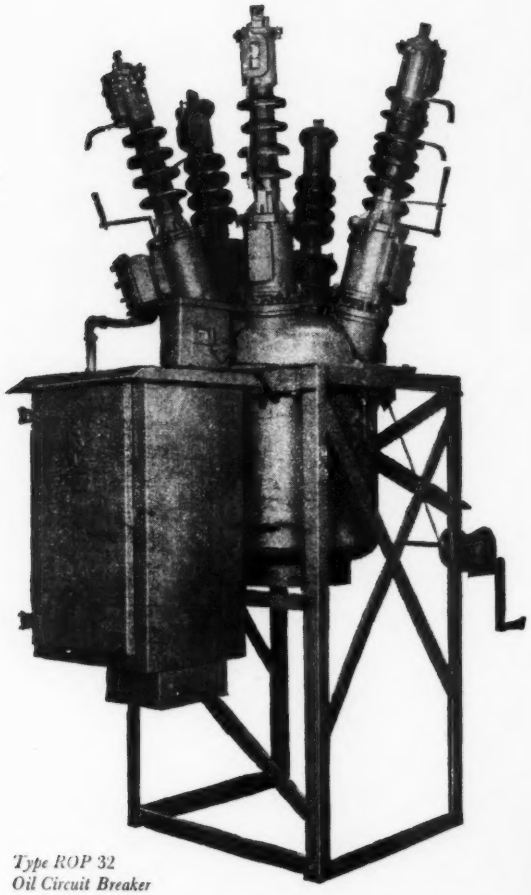


—the answer is *Ferguson Pailin*

When the dam is built and the major constructional work completed the task of installing the electrical plant and the equipment must be undertaken.

Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.



Type ROP 32
Oil Circuit Breaker

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

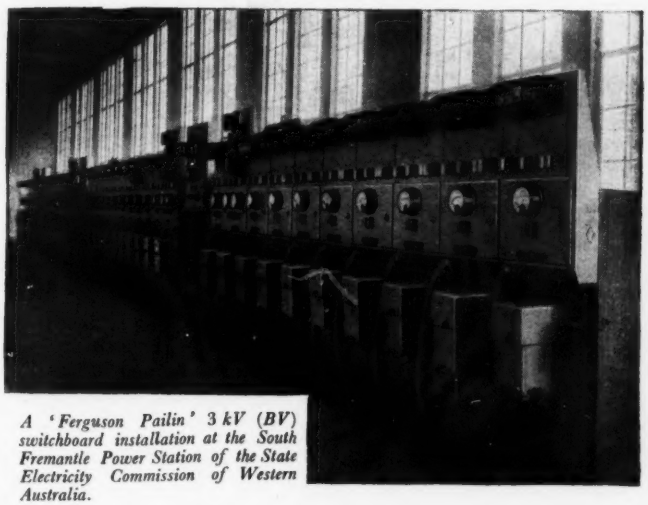
The versatility of the 'ROP 32' makes it remarkably adaptable to local requirements. Complete dependability and reliability make it a natural choice for incorporation into any scheme involving the transmission of power at 22 kV or 33 kV.

The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

'BV' SWITCHGEAR

'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

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mt

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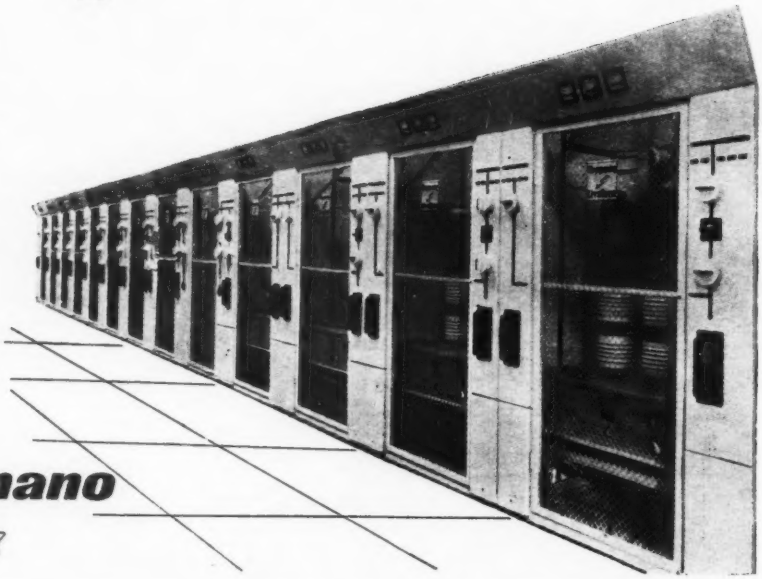
Hundreds of MT circuit breakers have been in fact supplied, not only in Italy, but also to Finland, Sweden, New Zealand, Ireland and Turkey, everywhere obtaining a bright success.



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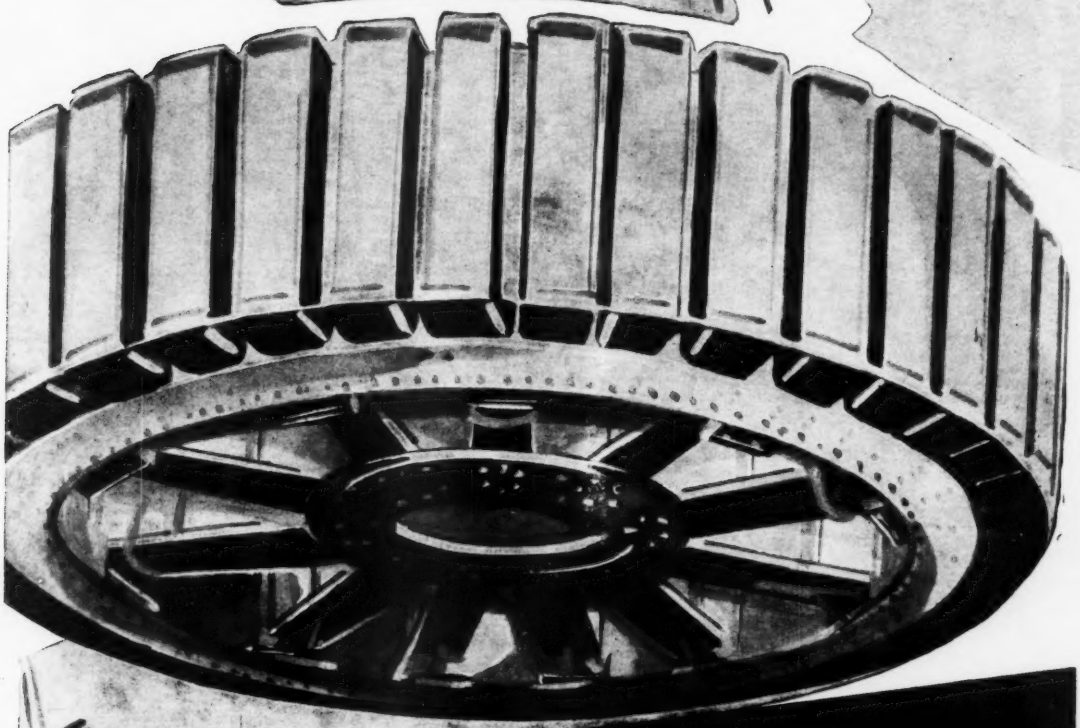

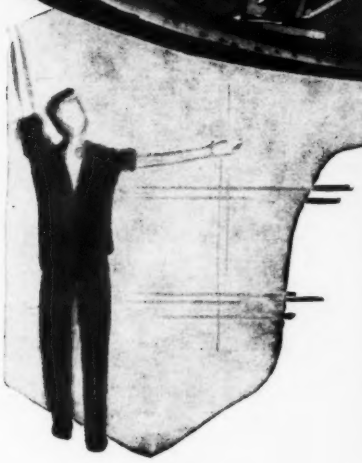

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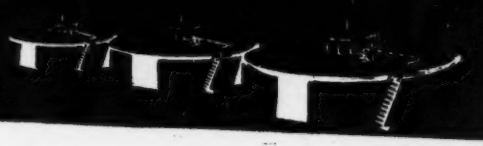

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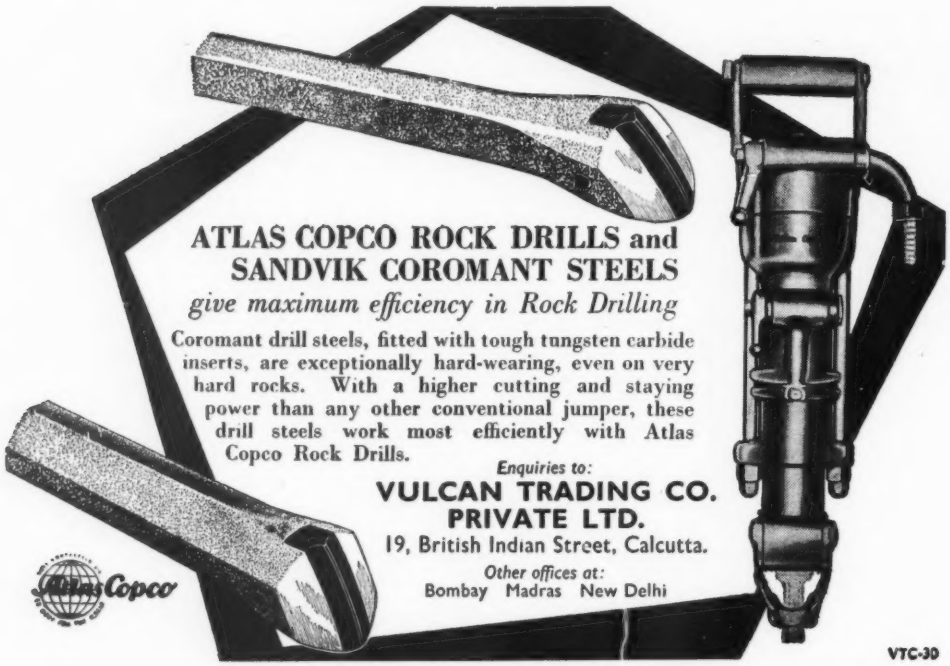

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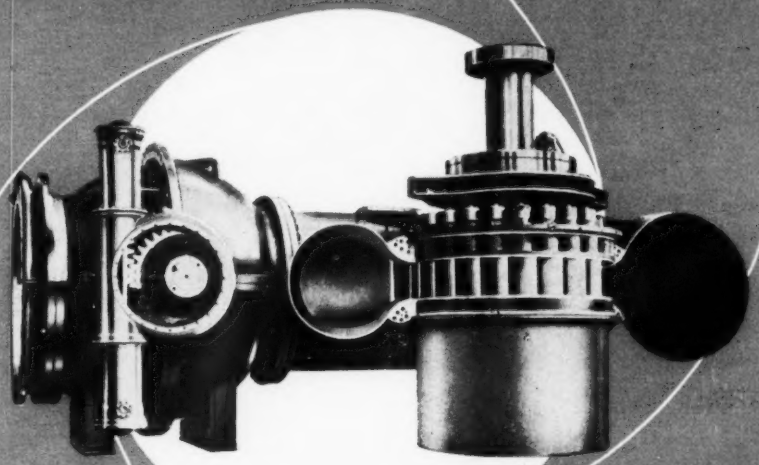

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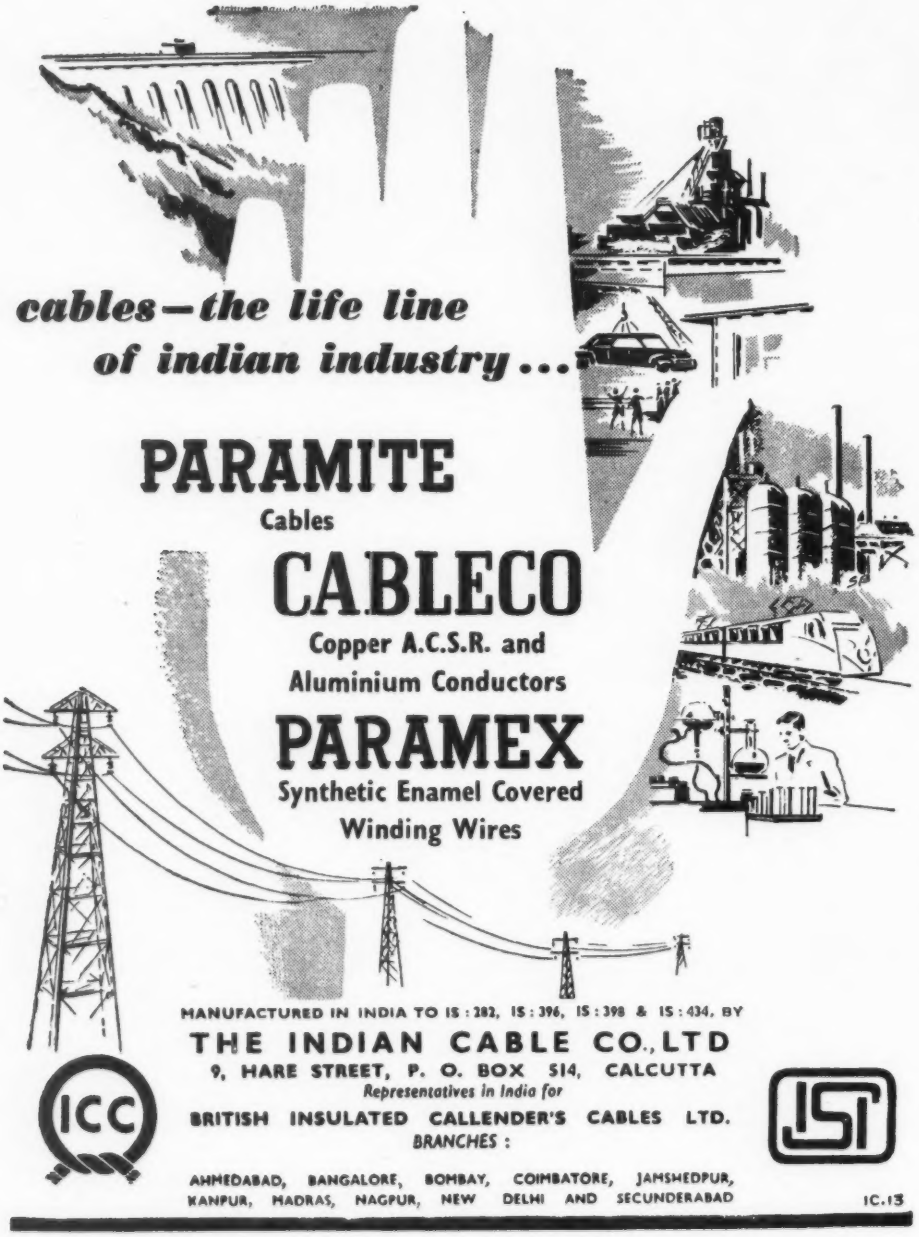
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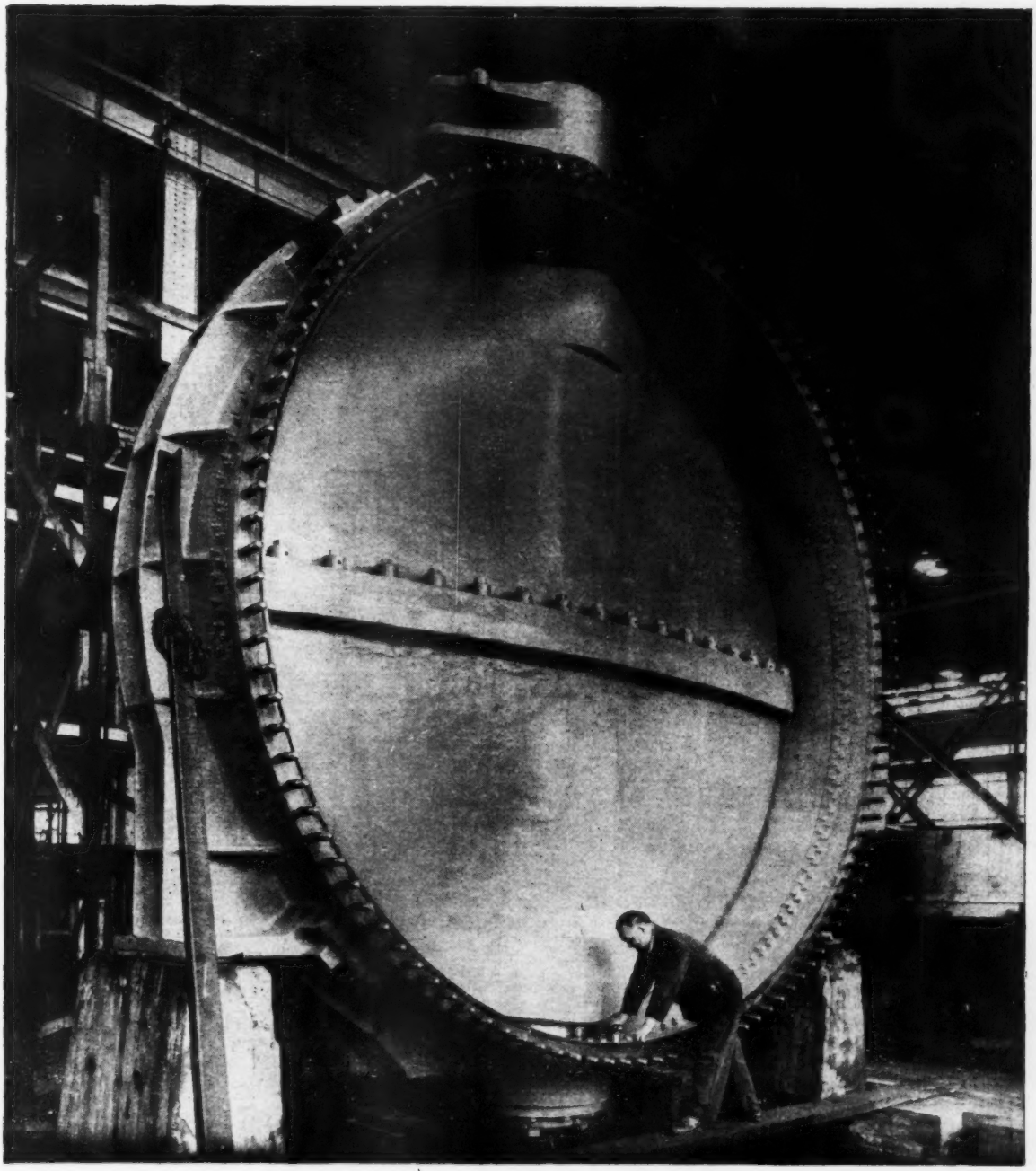

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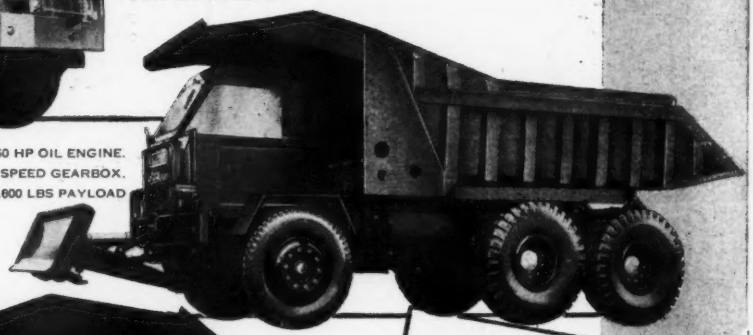

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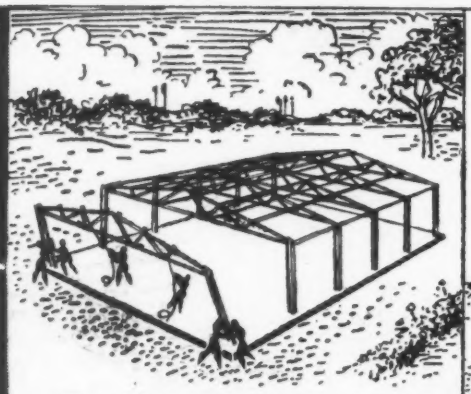

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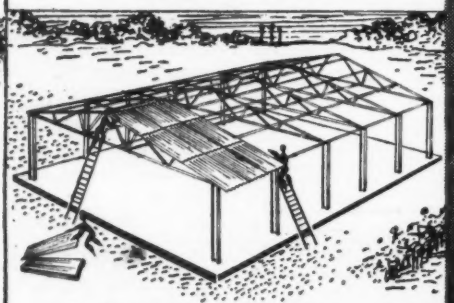

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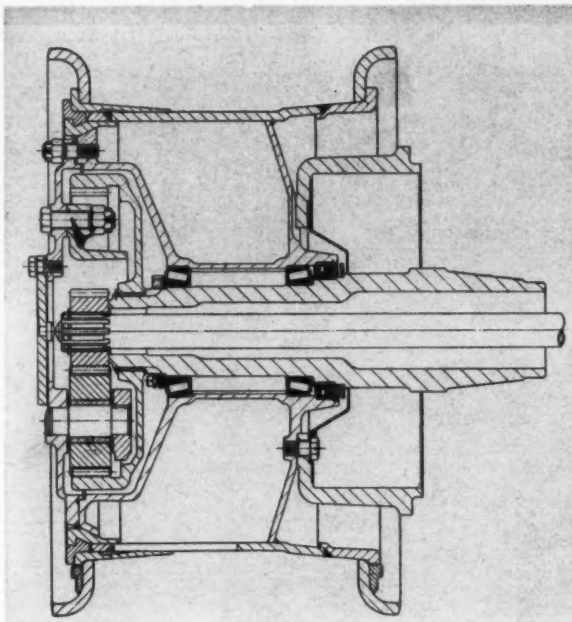

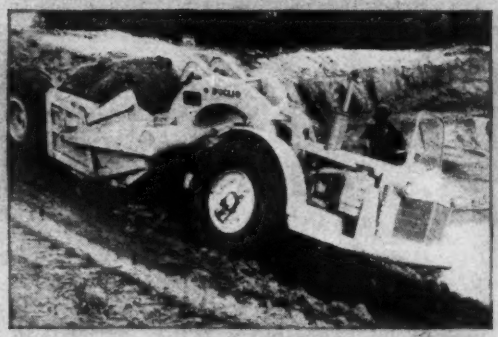

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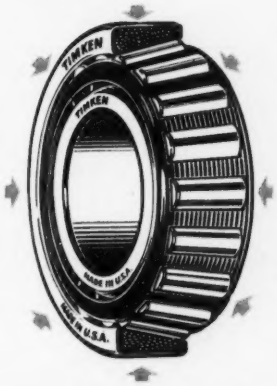

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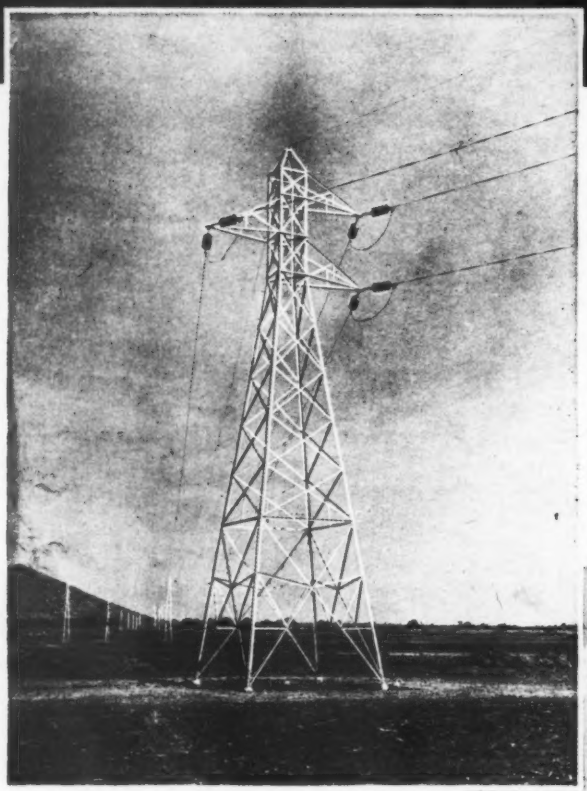

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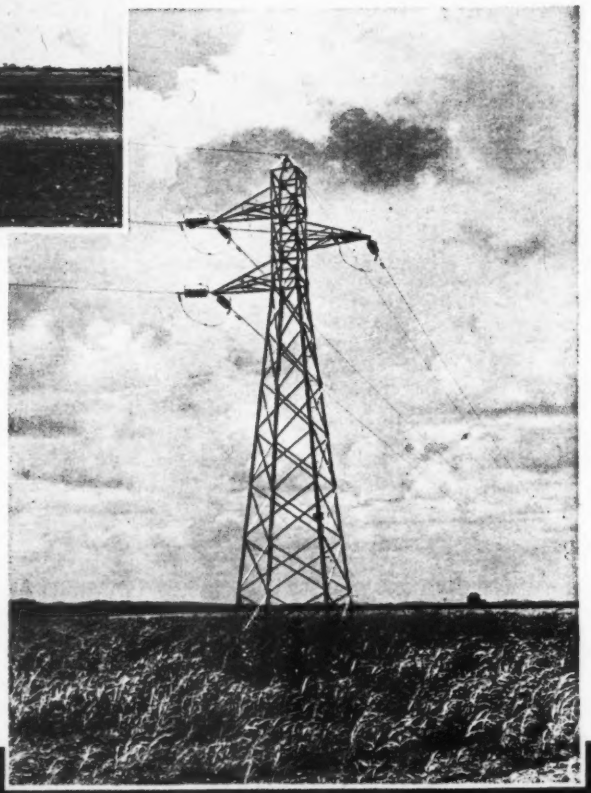

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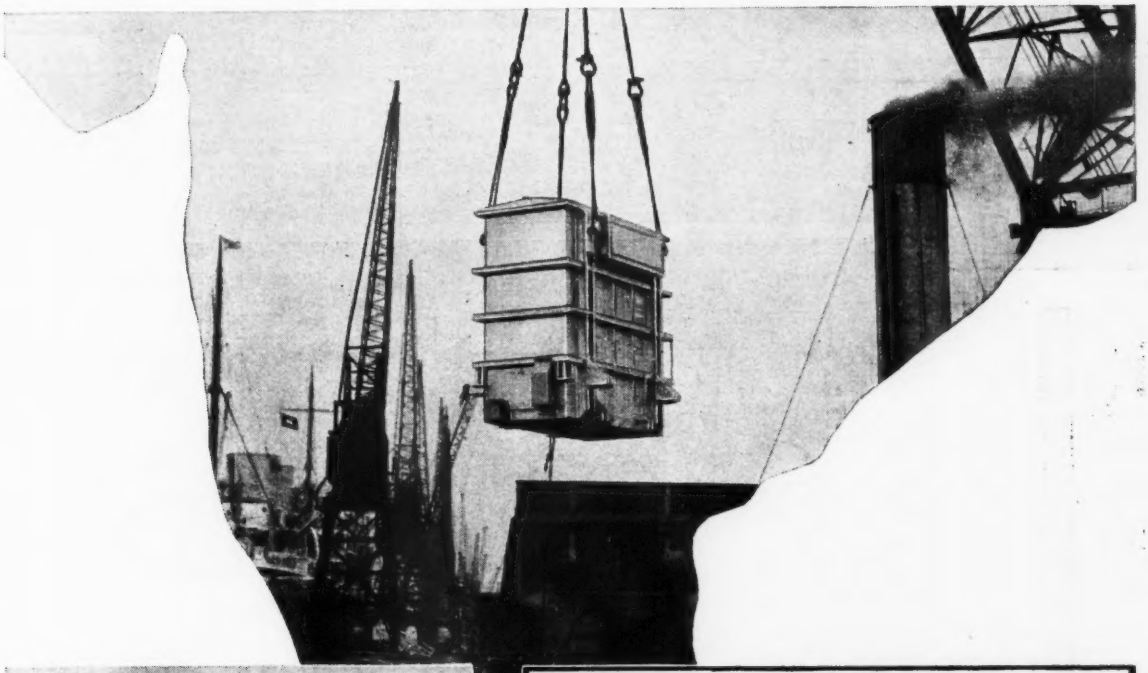

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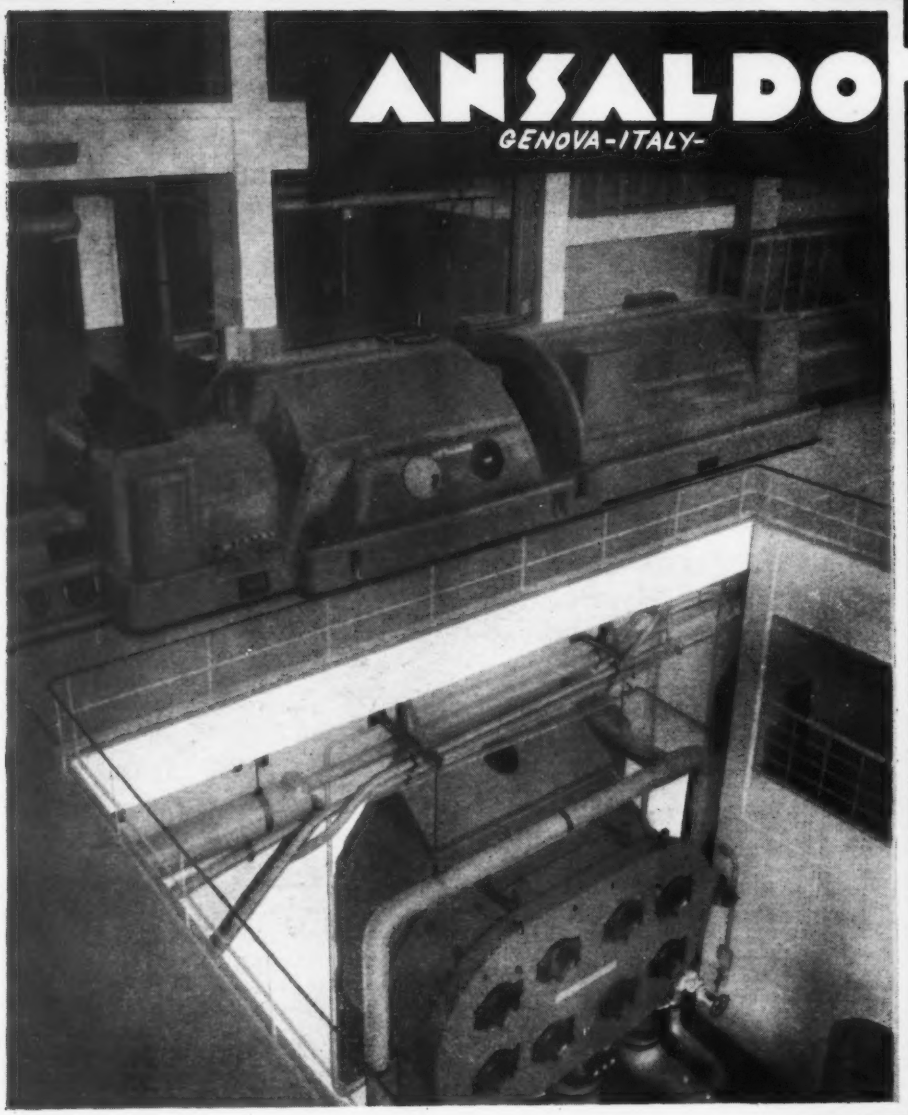

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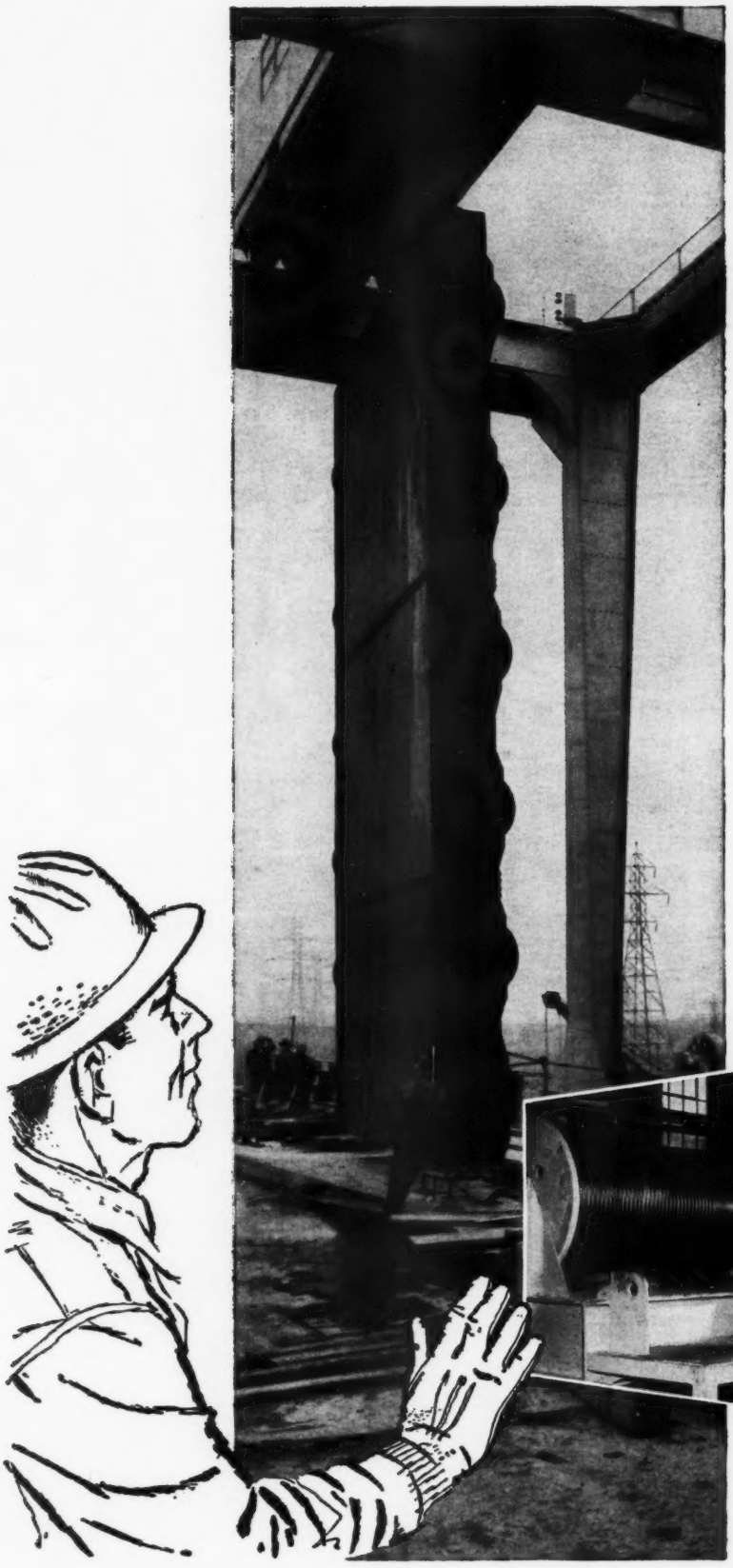

Intake Gates

Illustrated is a completely assembled Intake Gate being lowered into position. This is one of twelve built by Canadian Vickers for the Pumped Storage Scheme part of the Sir Adam Beck No. 2 Development of the Hydro Electric Power Commission of Ontario, at Queenstown.

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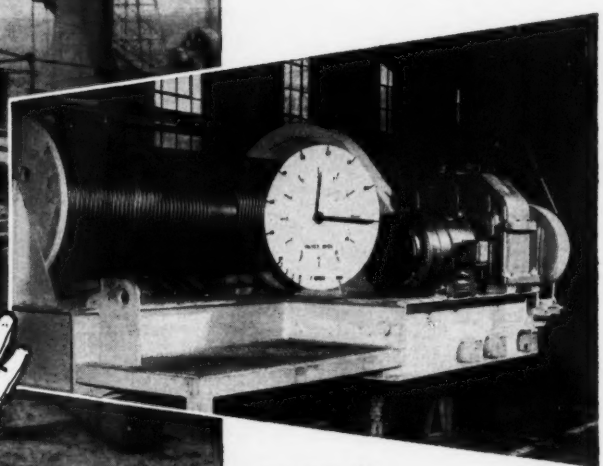

Shop photo of a Vickers-built Hoist.

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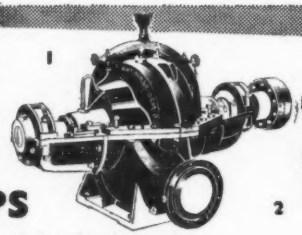

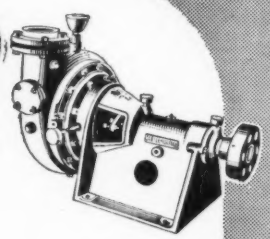

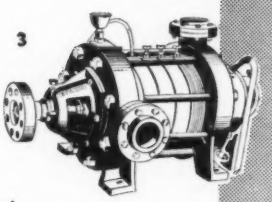

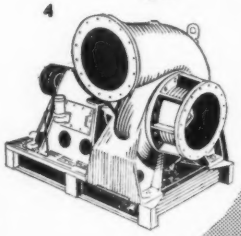

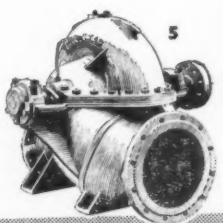

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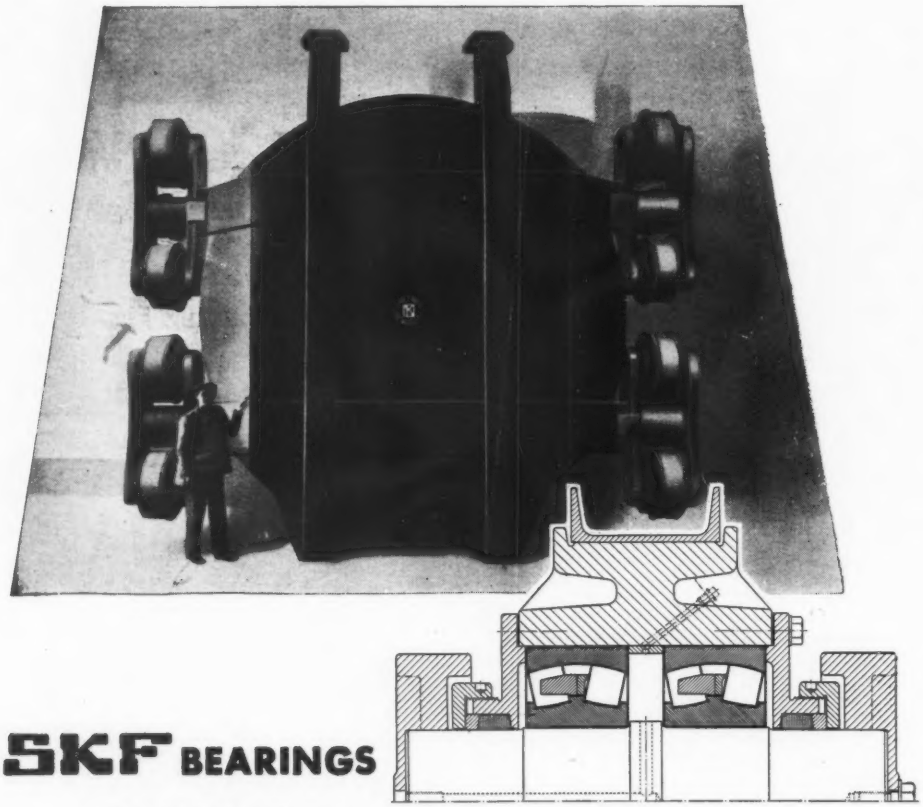

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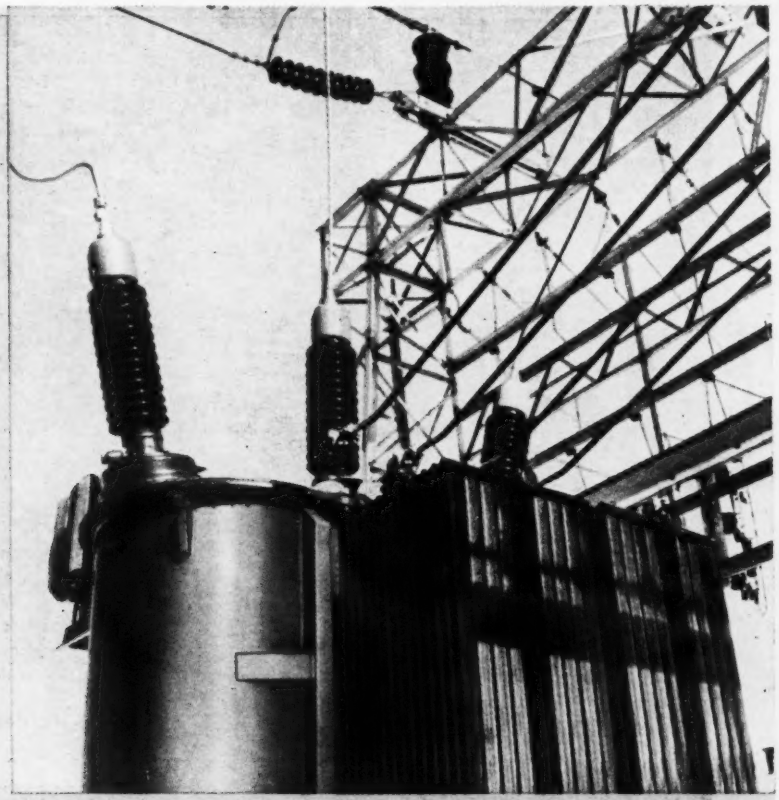

115,000 volt power transformer. Ontario Hydro photo.

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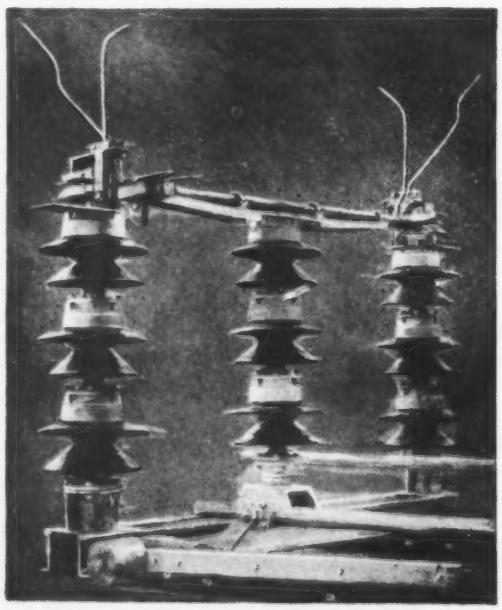

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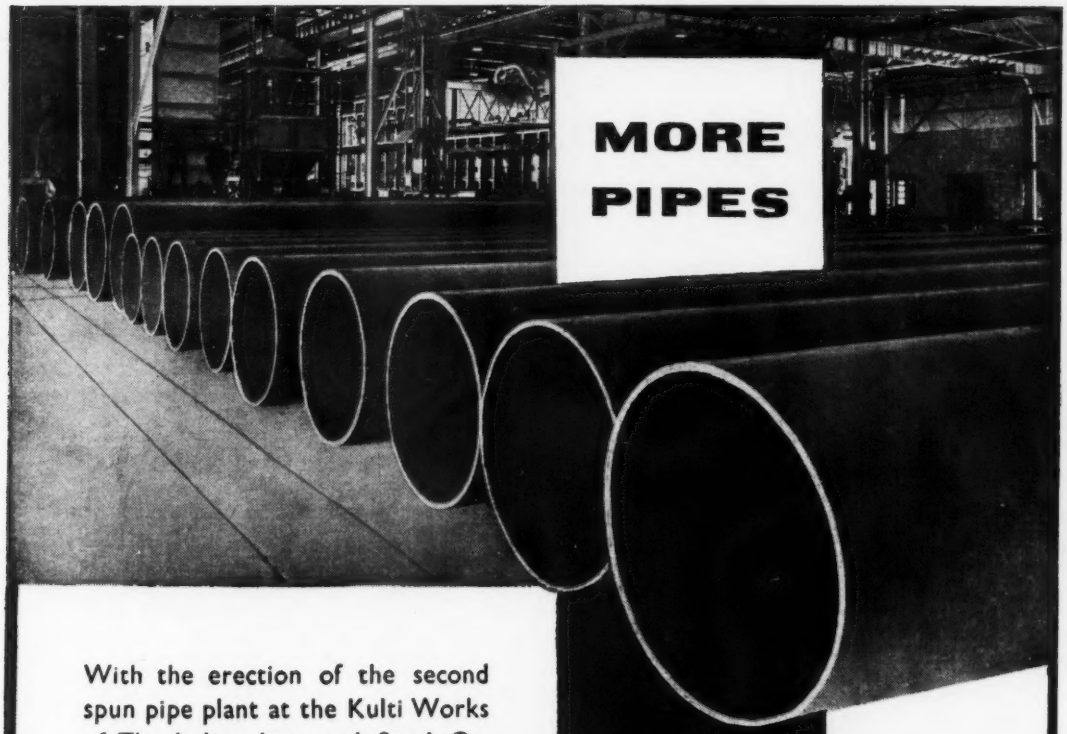

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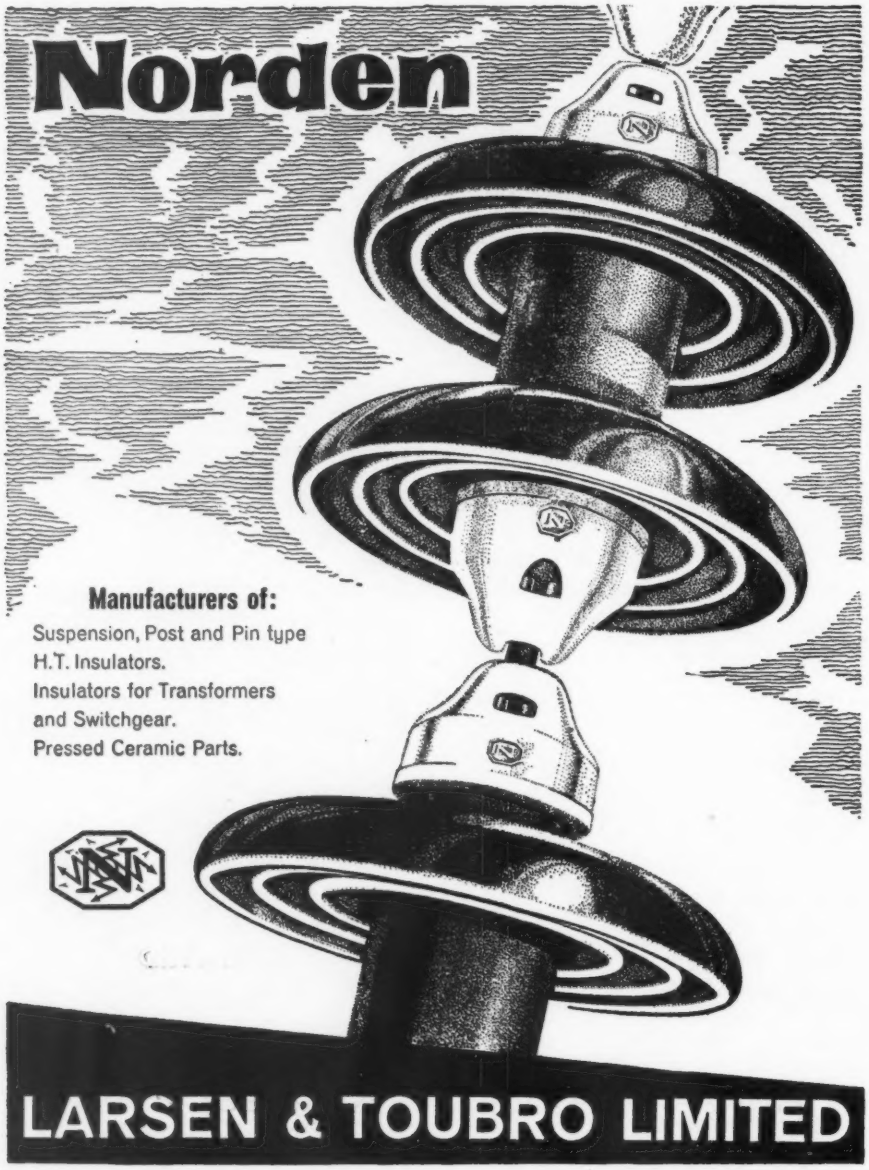

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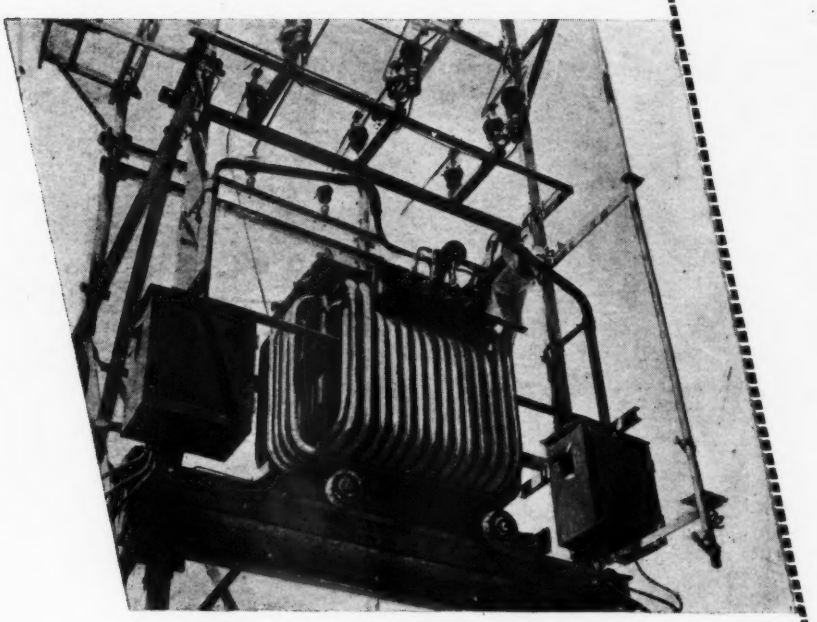

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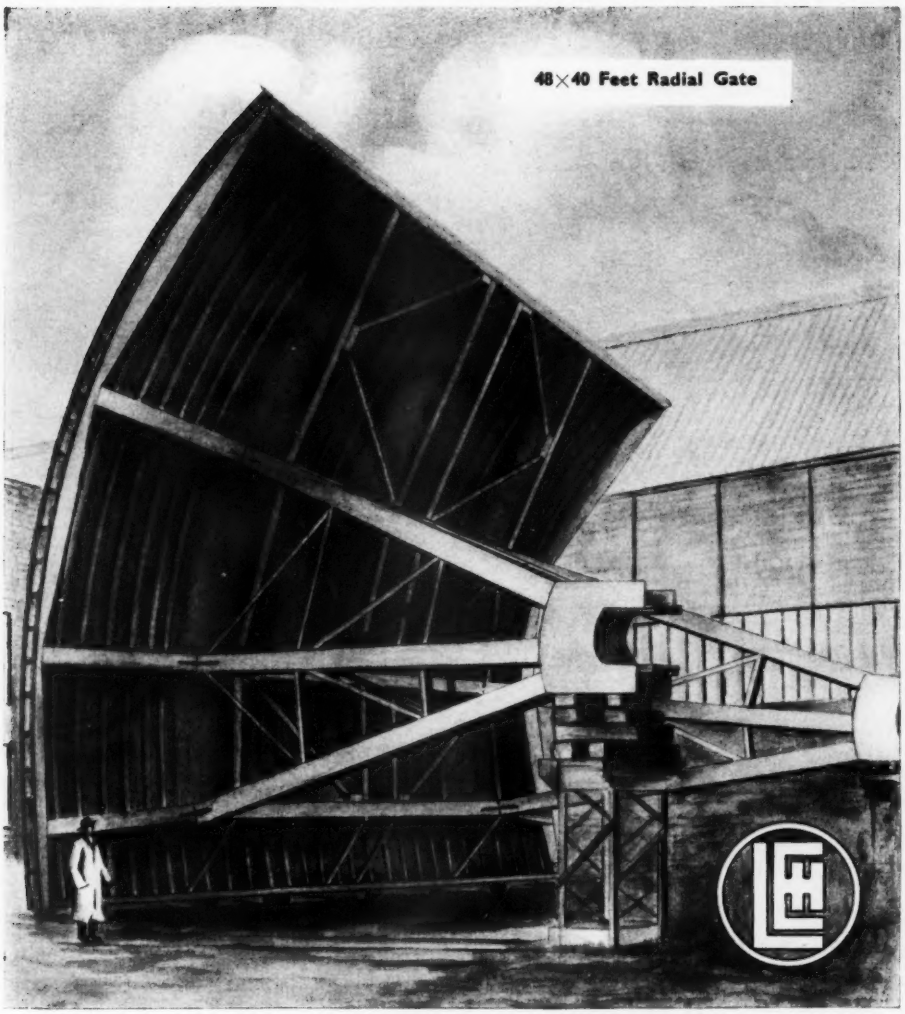

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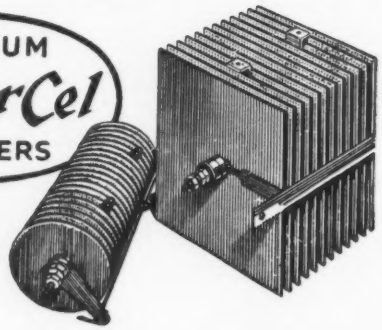

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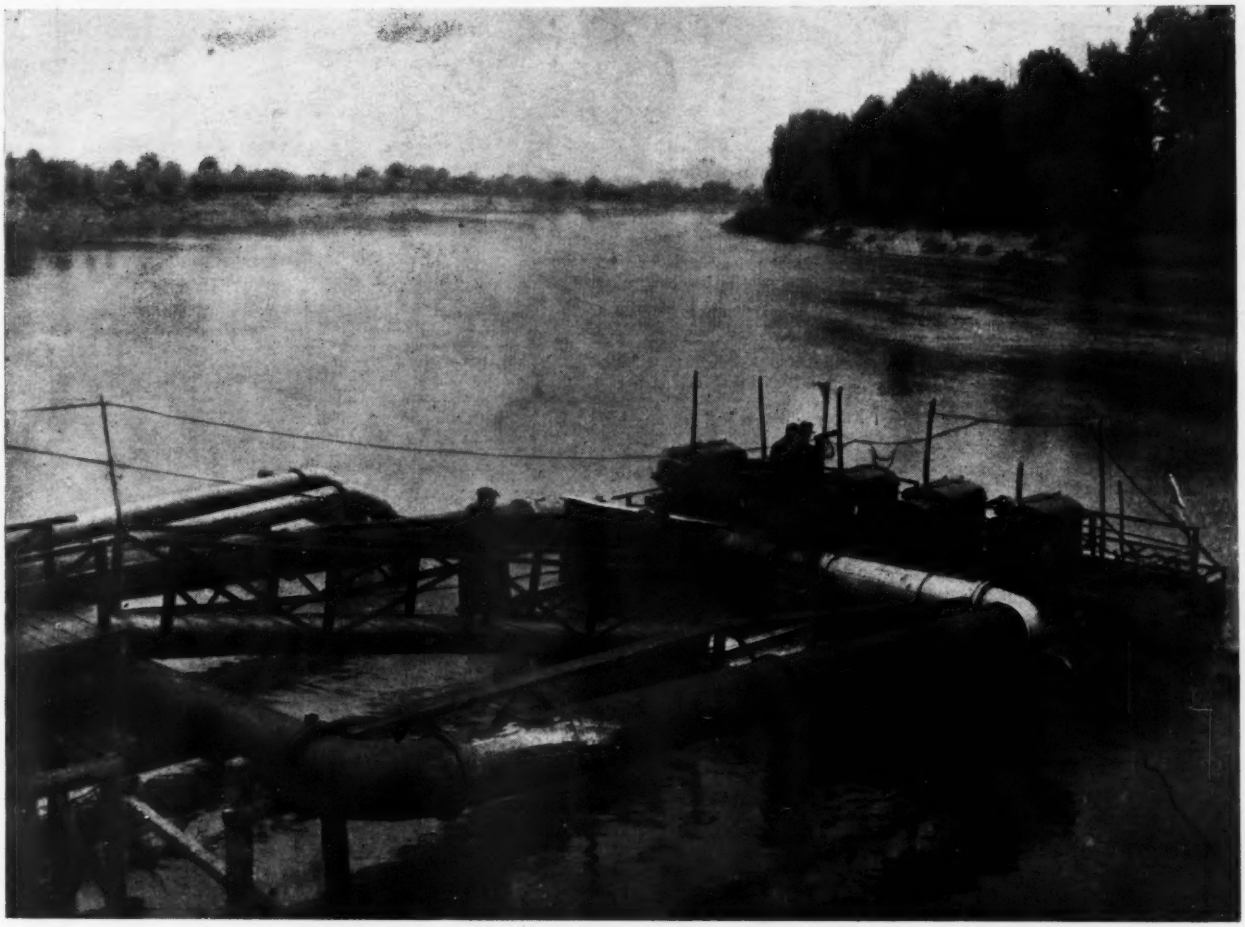

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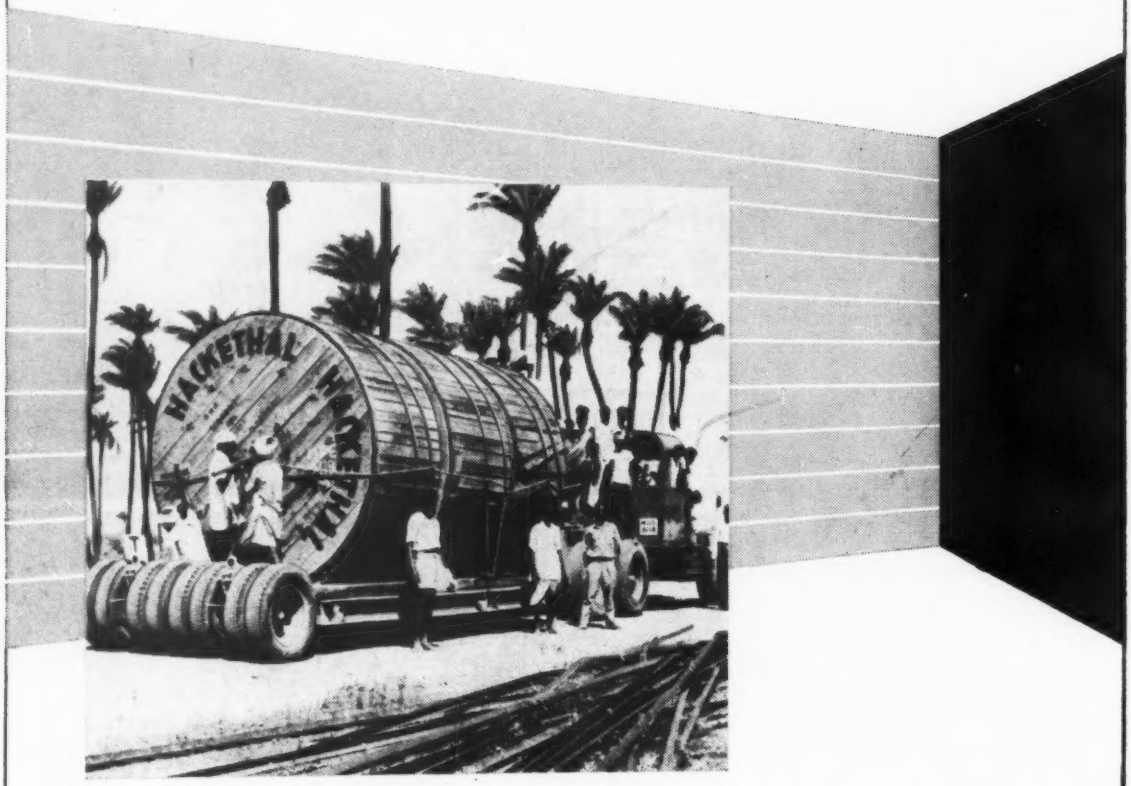

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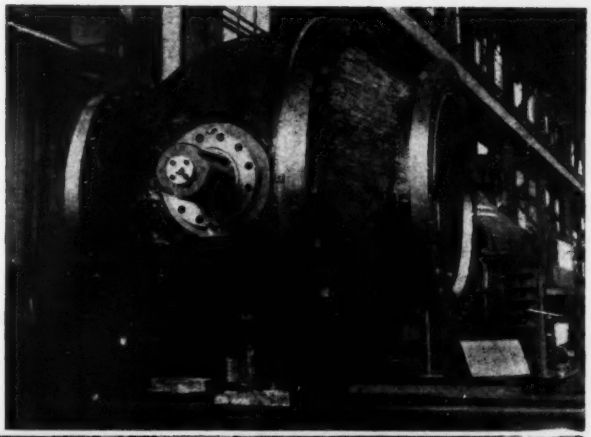

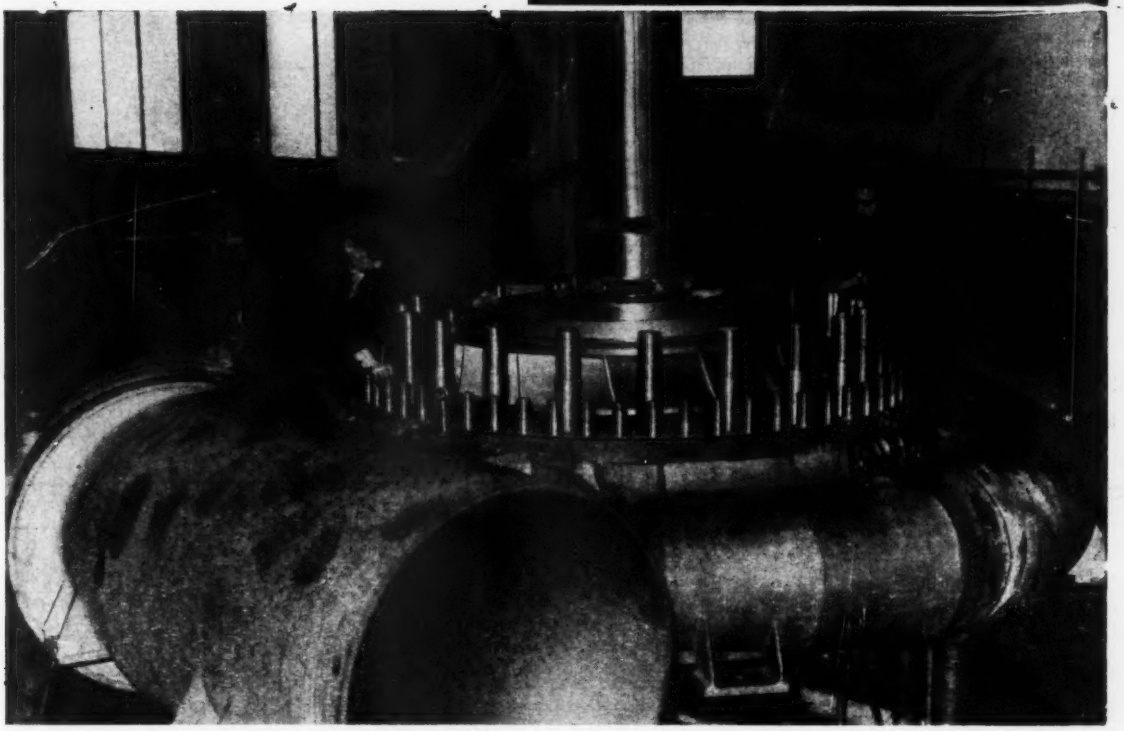

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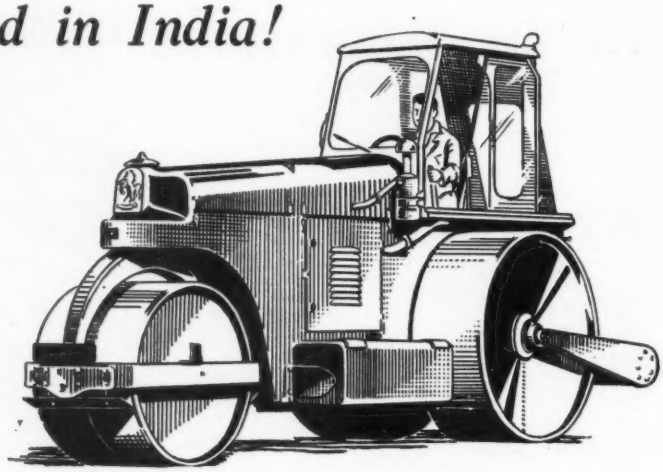

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A MONTHLY DEVOTED TO DEVELOPMENT OF POWER & WATER RESOURCES IN ASIA

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Introduction

With the achievement of political independence, India has entered a phase of economic development that will know no pause till at least the end of this century. This means that all the States in the country will feel the pressure of increased demand for electricity. But the regions that were relatively less developed than others would naturally ask for a more rapid pace of development. The last ten years amply indicate this trend in Madras State. Although it ranks only third in generation and utilisation in India, it shows a determination and an urge for growth much faster than in the past. This is as it should be.

But human urge by itself is not enough. The material resources for generation of power is also required. Most of the hydro-electrical potential in Madras has already been tapped. A few of the remaining ones are being fast explored for utilisation. Neither coal nor oil is available; but a large quantity of lignite is now being exploited both for power generation and briquetting. But even this source will not prove enough for long. There is thus a case for an ultimate generation of atomic power. The "Atoms for Peace" conference held this year at Geneva, must therefore come as a welcome gust of fresh air to not only Madras, but also to other areas similarly situated. Dr. Bhabha strongly pleaded the case for atomic power in India, and other leading foreign scientists have now agreed that in under-developed regions nuclear power may soon compete favourably with power from conventional sources for several reasons. It would, therefore, be worthwhile for Madras to begin consideration of this source of power with greater detail and set up at least a study cell for the purpose.

This, however, in no way minimises the importance of investigating and exploiting the existing sources of power. Madras, therefore, has done well in investigating and finalising such projects as the Mettur Tunnel Scheme, the Kumbar-Amaravathi Scheme, the Palar-Porandalar Scheme and the ultimate phase of the Kundah project. Perspective planning and planning for meeting needs of the immediate future should go hand in hand.

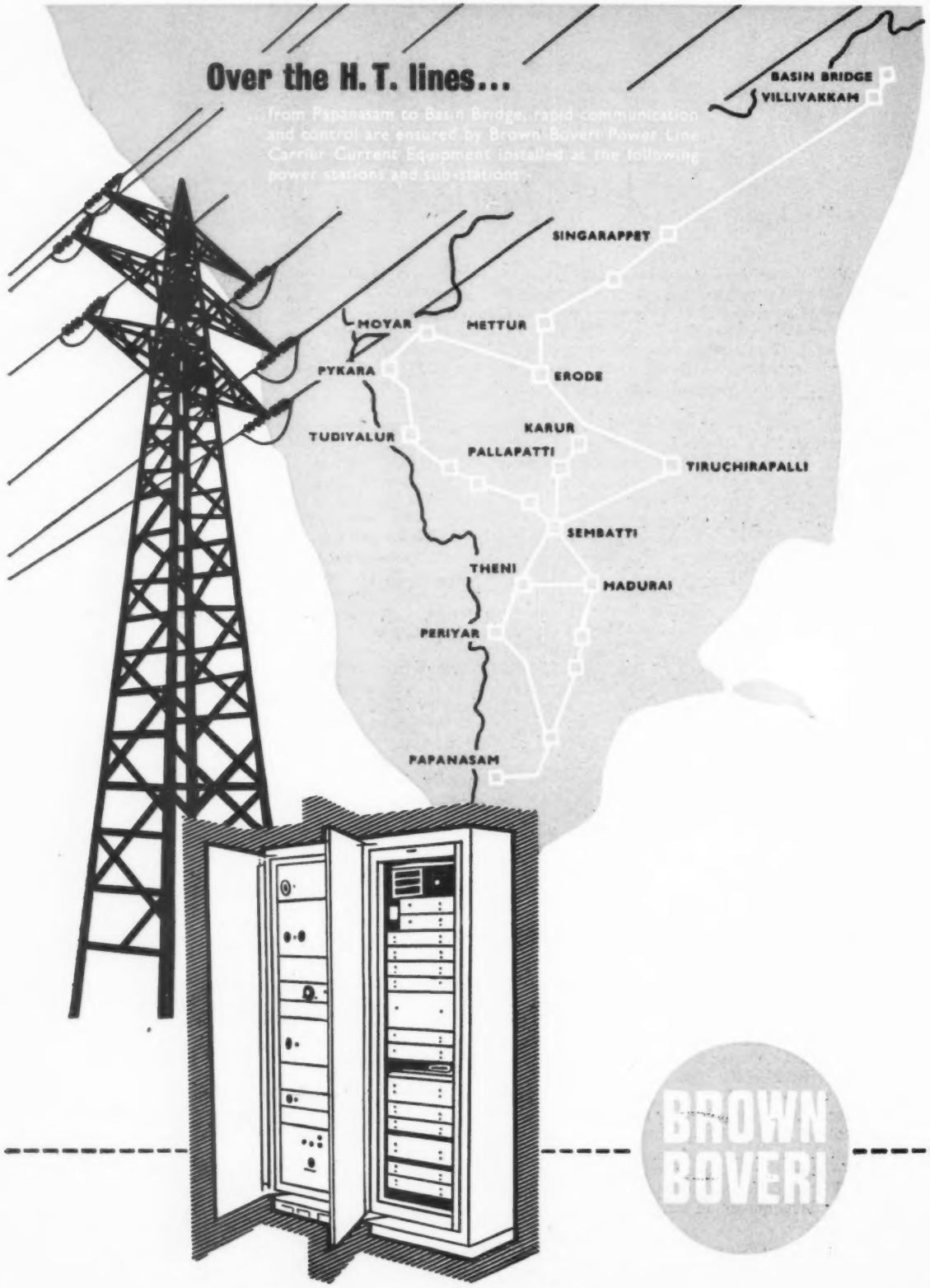
Madras may not lead in terms of generation capacity, but it has an enviable record in the development of the Madras Grid. It has succeeded in making power available literally to every nook and corner of the State. Such a fuller and comprehensive coverage by electricity is indeed a great achievement and shows the foresight and perseverance of those who have been and are responsible for its planning and execution.

This indeed is the reason for Madras' lead in rural electrification. India being a country of villages—and it will continue to be so till as far as one can foresee the future—one of the major standards of measure of progress should be the extent and degree of rural electrification. Measured thus, Madras has left most of the States far behind, and it is keeping up this lead.

But that is not all. Even a cursory glance at the figures will indicate that the pattern of consumption of electricity in rural areas is most inspiring. Pumpsets for irrigation provide the most significant contribution. In fact, the demand for it each year far outpaces the practicability of supply. Then, rural industries constitute more than one-third of the total industrial services. What do these facts indicate? It means that in Madras electricity has already become a part and parcel of the community and productive life of the people.

Here then is an emerging model for the rest of the country, except for the small regions which will be highly industrialised and urbanised.

We hope the following contributions, published with the co-operation of the State Electricity Board of Madras, will provide a detailed insight into the prospects and problems of electricity development in that State.



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The Madras Grid

By V. P. APPADURAI

Power generation in the Madras State until about 1908 was confined mainly to a few tiny plants in tea estates run on water power, and to the small hydro installation at Kateri in the Nilgiris.

The first public electric supply in the State was commenced in Madras City in 1909 by the Madras Electric Supply Corporation under licence.

Real progress dates from 1925 when the Government of Madras initiated the policy of active development of the hydro electric power resources by the State.

In furtherence of this policy, the first hydro-electric scheme viz., the Pykara Scheme was taken up in 1929 and the station commissioned in 1932. The Mettur station came into operation in June 1937 and the Papanasam power house in April 1944. The first thermal station to be erected by the Department was commissioned early in 1951 at Madurai.

The first Five Year Plan was confined to construction of a new power house at Moyar and extensions to the existing stations at Pykara, Papanasam, Madurai and Madras. The installed generating capacity increased by nearly 65 per cent from 156,000 kW. to 256,700 kW.

Planning

To develop the available power resources in an orderly and rational way and make it available over the whole State cheaply and in abundance, the Electricity Department ever since its inception in 1927 has had as its objective the creating of an electric power grid covering the whole State. This grid was planned so that eventually it would link the several hydro-electric and thermal stations in the country and convey their power to consumers in all villages and towns through a network of transmission and distribution lines. All planning in the Department and all its activities are dominatedand controlled by this conception of a State-wide electric power grid.

The map on page 4 shows the Madras Power grid. It indicates the existing power houses and main transmission lines as also those under execution and those projected for construction in near future.

Power Grid

The Madras power grid covers all the districts of the State except the Kanyakumari District which has recently been formed after the reorganisation of the States. This district at present is getting power supply from the Kerala State and will be fed from the Madras grid as soon as the Periyar Power Station, now under construction, goes into operation. The grid comprises:

Four Hydro-Electric Power Houses

Pykara	.. 70,200 kW.	installed capacity.
Moyar	.. 36,000 kW.	,, ,,
Mettur	.. 40,000 kW.	,, ,,
Papanasam	.. 28,000 kW.	,, ,,

Two Thermal Power Houses

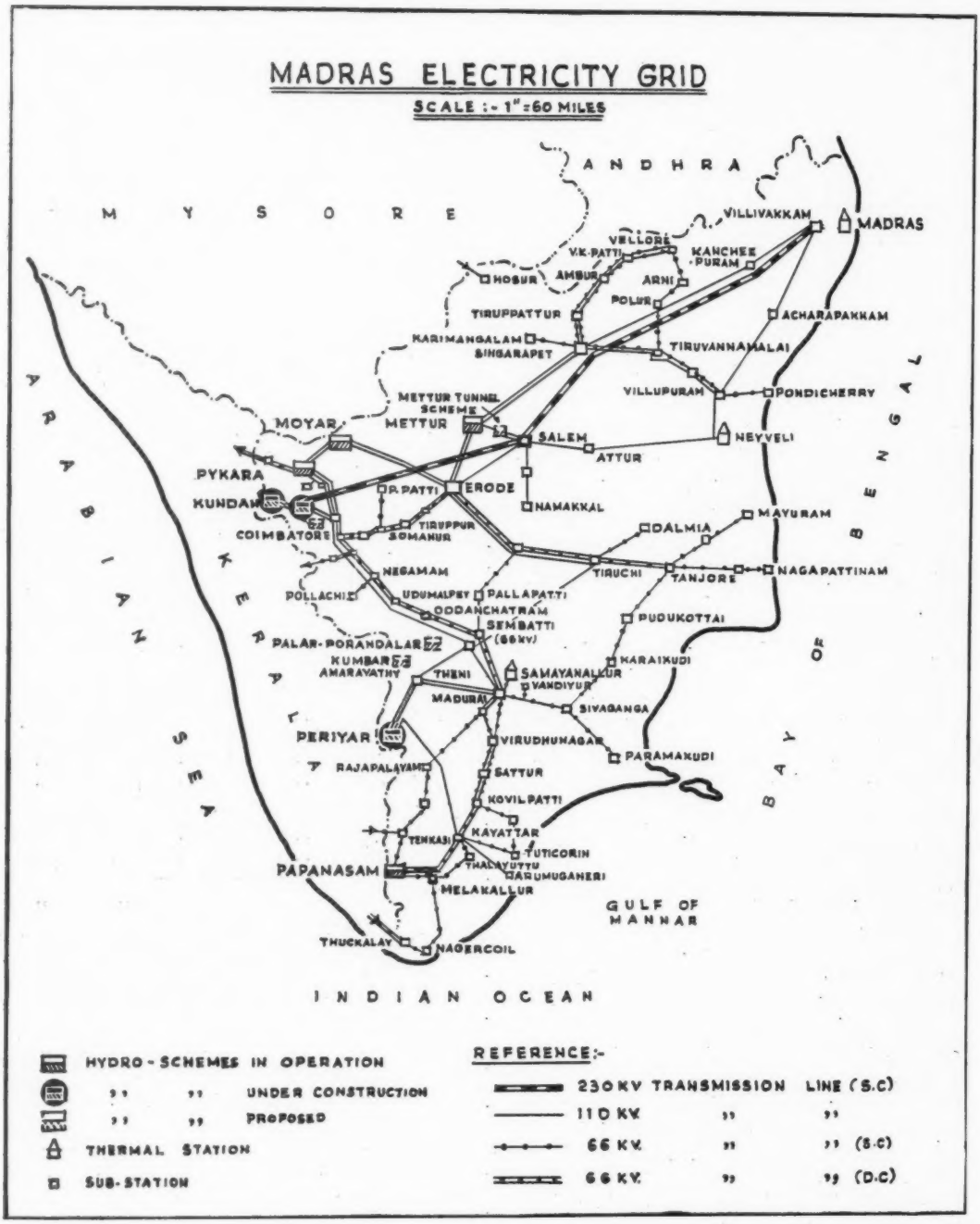
Madras	.. 98,500 kW.	installed capacity
Madurai	.. 14,000 kW.	,, ,,
Total	.. 286,700 kW.	,, ,,

And 10,500 miles of high tension transmission lines of voltages varying from 11,000 to 110,000 13,900 miles of low tension distribution lines and 56 EHT and 61 H. T. substations and 6,642 distribution stations.

The grid is serving electricity to 5 lakhs of consumers—about 80% of them served directly by the Board and the rest served through 5 municipal licencees and 8 private company licensees.

The peak demand met totalled 2,53,000 kW. Power generated last year was 1345 million units out of which about 76 per cent was from water power and the balance from coal. The entire power output in the State is produced by the Electricity Board.

The total capital investment to the end of April 1958 is about Rs. 81 crores and the annual gross revenue during the year is about Rs. 10.4 crores.


MADRAS ELECTRICITY GRID
SCALE :- 1" = 60 MILES
ANDHRA
MYSORE
VILLIVAKKAM
MADRAS
VELLORE
V.K. PATTI
KANCHEE PURAM
HOSUR
AMBUR
ARNI
POLUR
TIRUPPATTUR
ACHARAPAKKAM
KARIMANGALAM
SINGARAPET
TIRUVANNAMALAI
VILLUPURAM
PONDICHERRY
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METTUR
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SALEM
NEYVELI
ATTUR
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POLLACHI
UDUMALPET
PALLAPATTI
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SEMBATTI (66 KV)
PUDUKOTTAI
PALAR-PORANDALAR
KUMBAR
AMARAVATHY
THENI
KARAIKUDI
SAMAYANALLUR
VANDIYUR
MADURAI
SIVAGANGA
PERIYAR
VIRUDHUNAGAR
PARAMAKUDI
RAJAPALAYAM
SATTUR
KOVILPATTI
KAYATTAR
TENKASI
TUTICORIN
PAPANASAM
THALAYUTTU
ARUMUGANERI
MELAKALLUR
GULF OF MANNAR
THUCKALAY
NAGERCOIL
INDIAN OCEAN
ARABIAN SEA
BAY OF BENGAL
HYDRO-SCHEMES IN OPERATION
" " UNDER CONSTRUCTION
" " PROPOSED
THERMAL STATION
SUB-STATION
REFERENCE:-
230 KV TRANSMISSION LINE (S.C)
110 KV " "
66 KV " " (S.C)
66 KV " " (D.C)

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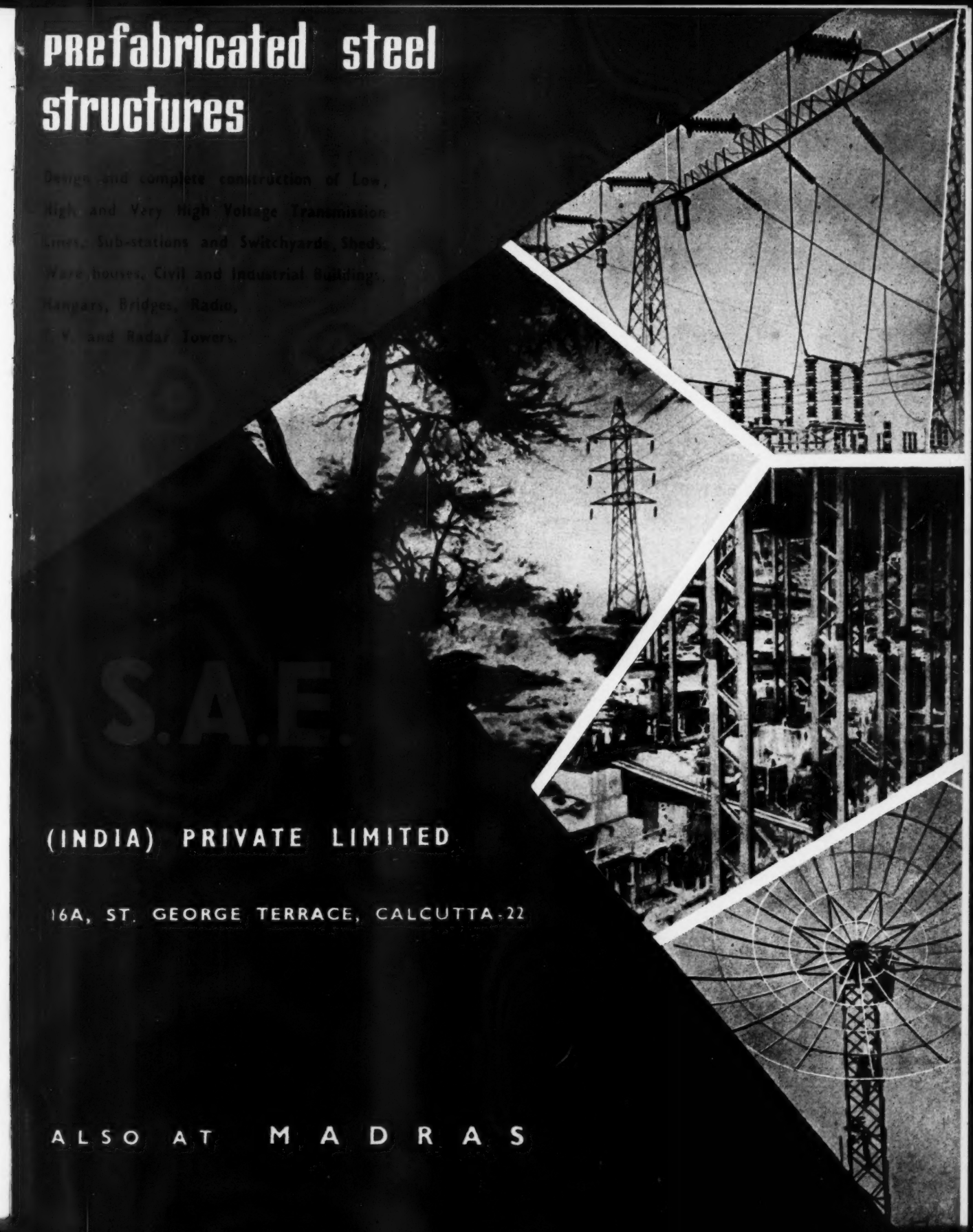

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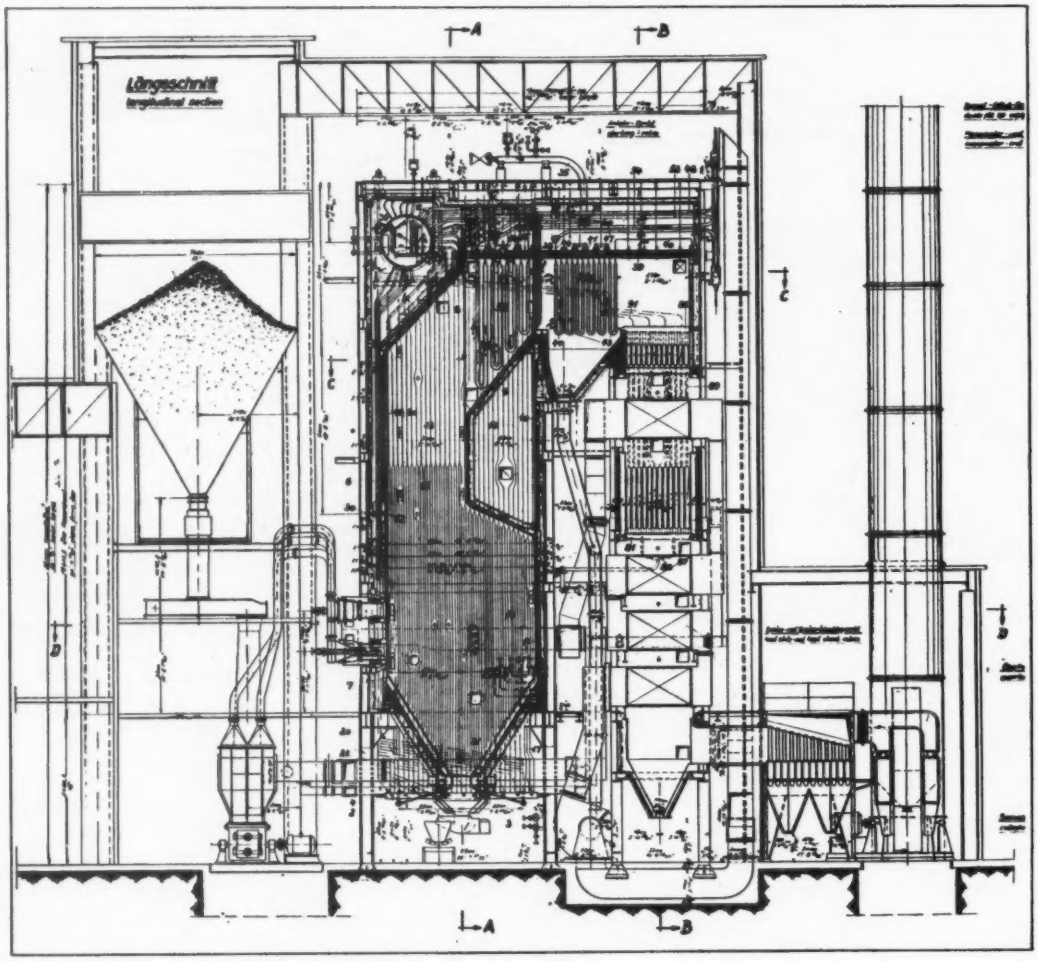

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Madras in the Power Map of India

Today Madras State ranks third in India in generation and utilisation of power, Bombay and Bengal leading. In respect of utilization of power for irrigation purposes it stands first by way of number of consumers, consumption and connected load. In the matter of hydro-electric output, Madras is second only to Bombay. While the bulk of the power in Bombay and West Bengal is consumed in big industries and urban loads, Madras has built up an electricity grid extending into almost all the districts and rural areas. In fact, Madras leads the rest of India in rurtal electrification with over 7000 towns and villages taking electricity supply by August 1958.

Second Five Year Plan

The power schemes of the Madras State included in the second Five Year Plan as originally approved by the Planning Commission were estimated to cost Rs. 60.03 crores. A five per cent economy cut suggested by the Planning Commission and the reconstitution of the Madras State subsequently reduced this to Rs. 532.25 crores. This forms about 33 per cent of total amount allocated to the State in the second Plan period and about 12 per cent of the total outlay on power projects in India.

Outlay and Targets

The Schemes included in the Plan together with the proposed outlay and physical targets are given in Table 1.

Table I.

Sl. No.	*Name of Scheme*	*Proposed expenditure in lakhs of Rupees.*	*Physical target (installed generating capacity)*
1.	Madras Plant Extensions	271	30,000 kW
2.	Transmission & Distribution	271	..
3.	Periyar Hydro Electric Scheme.	723	1,05,000 kW
4.	Acquisition of Electrical undertakings.	100	..
5.	Kundah Hydro Electric Scheme.	2000	1,80,000 kW
6.	Transmission & Distribution Project.	1360.84	**
7.	Pykara Dam Power House.	30	3,000 kW
8.	Papanasam Dam Power House.	41	4.000 kW.
9.	Sandyanallah Reservoir Scheme	96.8	*
10.	Improvements to existing Power Houses, Transmission Lines and Substations.	250	..
11.	Investigation of new Schemes.	19.5	..
12.	Acquisition of Electrical Undertakings (Additional)	162	..
	Total	5325.14	

** 5,000 Villages will be electrified during the Plan period.
* The Scheme when completed will increase the energy that can be generated at Pykara and Moyar Stations by about 54 million units annually.

Progress

Generation: The Madras Plant Extensions (III Stage) which envisaged the erection of a 30,000 kW. set with two numbers 150,000 lbs./hr. boilers have recently been completed.

The first unit of Periyar H. E. Scheme has just been commissioned and the second and third units are expected to be commissioned within a period of six months.

For the Kundah H. E. Scheme, Civil works are in full swing in all the dam sites, tunnels, and the power house sites. The first unit, in both the power houses are programmed to be commissioned by March 1960 and the initaial phase within the Plan period.

Transmission and Distribution : The transmission and distribution project envisages the construction of a number of secondary transmission lines required for taking the additional power to the remotest corner of the State. Including the transmission lines proposed under the Kundah and Periyar Hydro-Electric Schemes, an additional 8,200 miles of EHT and HT lines and 8,000 miles of L. T. lines will be erected during the Plan period. Of these, 3122 miles of E. H. T. and H. T. lines and 5739 miles of L. T. lines have already been erected during the first two years of the Plan period. A major stride in respect of transmission during the second Plan period will be the erection of the first 230 kV line in the State from Kundah to Madras which will convey power generated at Kundah to Madras—a distance of about 300 miles. In addition to the transmission lines, the scheme is also intended for rural electrification and to bring electricity to the nooks and corners of the State

Rural Electrification : Madras continues to maintain its lead in the matter of rural electrification with over 7,000 towns, villages and hamlets electrified by August 1958. During the second Plan period it is proposed to extend electricity to 5,000 additional villages. Of these about 2,620 have already been electrified during the first two years. About 32,440 pumps were working on electricity at the end of the first Plan period. During the first two years of the second Plan period more than 30,000 pumpsets, were connected bringing the total at the end of the second year to 63,000.

Table 2 gives the power development of the Madras Grid under the Five Year Plans. It may be seen from the table that there has been a phenomenal development during the last four years.

Industrial Development in the State

The power demand of the Madras Grid has been steadily on the increase. During the second Plan period, large scale industrial development, both in private and public sectors requiring large blocks of power has been contemplated. The important industries coming up in the Madras State are the aluminium industry in the public sector proposed to be established in the Salem District and caustic soda-cum-soda-ash plant in the private sector to be established in Arumuganeri in the Tirunelveli District. These two industries alone would require about 50,000

to 60,000 kW of power. A raw film factory proposed to be established in Ootacamund would require about 24000 kW. The paper industry proposed to be estabilshed in the State would require power to the extent of 24000 kW. The cement industry would require power of 12000 to 14000 kW. Enquiries have also been received for power for setting up a rayon industry in the private sector. Apart from these, the Board will have to meet the growing requirements of the small scale industries and also the lignite mining load till the thermal station proposed there commences operation.

Madras at the end of the Second Plan

When the schemes in the second Plan are completed, the installed capacity, aggregate demand, units generated and the length of lines will all be more than doubled. The Grid is expected to cater power to about 7,00,000 consumers. In the rural areas, about 10,000 village and and 100,000 pumpsets will derive the benefits of electricity. The per capita consumption of electricity which is a recognised index of the economic advance of any State was 25 units at the end of the first Plan period. This figure has now increased to 36 units and it is hoped to raise this figure to 60 units by the end of the second Plan period.

TABLE II

Electricity Development under the Five Year Plans

Sl. No.	*Particulars*	1950-51 *Before the First Plan*	*First Five Year Plan*					*Second Plan*	
			1951-52	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58
I.	*Generation* :								
	Installed Generating Capacity in M.W.	157.4	163.80	200.33	225.6	256.7	256.7	256.7	286.7
	Aggeregate demand in MW.	130.8	146.00	143.60	151.9	181.6	208.6	233.85	252.35
	Units generated in Millions.	630.97	730.85	701.66	758.7	933.6	1053.28	1135.20	1344.92
II.	*Transmission* :								
	Length of E.H.T. & H.T. lines in miles.	4355	4829	5022	5420	6101	7343	9065	10,465
	Length of L.T. lines in miles.	3580	4498	4926	5140	5932	8128	11006	13,867
III.	*Rural Electrification* :								
	Number of villages electrified.	1613	1820	1981	2089	2392	3321	5016	6,373
	Number of pumpsets connected.	14,373	15,904	18,481	21,733	24,654	32,440	45,173	62,561
IV.	*Miscellaneous* :								
	Number of distribution transformers.	1591	1884	2092	2197	2648	3773	5286	6642
	No. of consumers in lakhs.	2.50	2.94	3.22	3.41	3.57	4.26	4.59	5.0
	Gross revenue in lakhs of Rs.	336.71	409.85	431.45	480.51	597.25	703.08	815.43	1033

Future Plans

The power demand of the Madras Grid has been steadily on the increase. To meet the growing demand which is expected to be of the order of 549,000 kW in 1961-62, new power sources have to be tapped. Two of the most important schemes, the investigation of which have just been completed, are the Mettur Tunnel Scheme to utilise the irrigation discharge at Mettur Dam which will give 200,000 kW seasonal power for seven months and the Kumbar-Amaravathi Hydro Electric Scheme in the Palni Hills which will add 20,000 kW to the Grid. The field investigation of the Palar-Porandalar Scheme in the Madurai District have just been completed while the investigations of Kundah ultimate phase is under progress.

The integrated Neyveli Lignite Scheme of the Government of India contemplates the erection of a thermal station of 250,000 kW capacity and it is expected that about 200,000 kW of power would be made available to the Madras Grid.

Nuclear Generation

With the exhaustion of the development of the potential water sources from which power can be developed economically the Board may have to resort to nuclear generation.

Today nuclear generation is characterised by high capital cost and it has been necessary to run these stations at high load factors for economic operation.

Coal costs have been continually rising and have gone up by over 50% in the last 12 years. Large coal fields are situated only in Bengal and Bihar and coal is to be transported over a distance of about 1300 miles. It may reasonably be expected that the pit head price of coal will increase during the next few years while the cost of atomic power will become progressively cheaper as a result of technical advances leading to higher operation, temperature, higher efficiency and lower capital cost. Atomic energy is expected to provide the primary necessity of all industrialisation viz., electric power with less burden to the economy than coal in regions remote from coal fields. Installation of an atomic reactor in Madras State will therefore become imminent either in the third or fourth Plan period to meet the ever-increasing demand of the State.

We hope to march ahead in the field of socio-economic development of our State by the spread of electricity, especially to the rural areas, and raise the standard of living of the common man and bring brightness and happineotss every home.

Rural Electrification in Madras State under the Five Year Plans

By V. P. APPADURAI

The present Madras State has an area of 50,170 sq. miles and comprises about 19,900 revenue villages and about 300 towns. Of a total population of about 30 millions, 75% i.e. 22.5 millions live in villages. To Madras, as for the rest of India, rural electrification has therefore a special significance as it would improve the economic status of rural population by increasing the food productivity and promote rural welfare by providing an environment equal in comfort and convenience to that enjoyed by the rural population. Rural electrification is therefore a powerful factor to prevent the exodus of the rural population to urban areas where higher wages and greater amenities exist.

First Five Year Plan

The first Five Year Plan for Madras State had yielded record results in various spheres and particularly in the development of electricity. A target of extending supply to 250 villages per annum (1,250 villages for the entire Plan period) was fixed for the composite State of Madras. The actual achievement for the "Residuary State" (i.e. after the partition of Andhra State) was extension of supply to over 1,700 villages and connecting up more than 18,000 pumpsets. This is much more than the targets fixed for the composite State. This was achieved mainly due to the increased activities in the sphere of rural electrification during the last two years of the first Manperiod, consequent on the Government of India granting a loan of Rs. 3 crores for this purpose. During the last two years of the plan period 1,231 villages were given the benefits of electricity as compared to 1,707 villages during the entire first Plan period. About 3,000 miles of H.T. lines and 4,500 miles of L.T. lines were erected during the first Plan period for taking cheap electric power to the villages.

Table I below gives the All India and Madras achievements in respect of extension of supply to villages and towns during the first Plan period.

At the end of the first Plan period 3,320 villages were electrified in the Madras State. Though Madras leads the rest of India in rural electrification, it has to be admitted that we are still on the fringe of the problem of spreading electricity to all the villages and hamlets of the State.

Second Five Year Plan

Outlay and Targets : The power schemes of the Madras State included in the Second Five Year Plan are estimated to cost Rs. 53.25 crores. The provision for transmission and distribution project in the power plan amounts to Rs. 1632.00 lakhs The transmission and distribution project envisages the construction of a number of secondary transmission lines required for taking the additional power to the remotest corners of the State for increase in production of agriculture and for processing rural and agricultural industries.

In view of the considerable importance attached to rural electrification the first Five Year Plan target of extending supply to 250 villages per annum was doubled when the second Plan schemes were formulated. This was revised to 1,000 villages per annum due to the keen interest of the rural people to have the benefits of electric power. The second Five Year Plan as at present schemed will result in an extension of supply to more than 5,000 villages during the second Plan period. Table II below gives the comparison of National and State targets during the second Plan period.

TABLE I

	All India			*Madras*		
	1950-51	1955-56	% increase	1950-51	1955-56	%increase
No. of villages and towns electrified	3,687	7,400	100	1,731	3,543	105

TABLE II

	All India			*Madras*		
	1955-56	1960-61	% increase	1955-56	1960-61	%increase
No. of villages and towns to be electrified	7,400	18,000	143	3,543	8,900	151

Progress : The actual achievements for the first two years of the plan period in the Boar's area alone are given below :—

1st Year	1956-57	1279
2nd Year	1957-58	1320

Table III gives the district wise break up of towns, villages and hamlets electrified as on 1-4-1958.

TABLE IV

1956-57	1st year of 2nd plan period	Rs. 514 lakhs (actuals)
1957-58	Second year	Rs. 439 lakhs (final grant)
1958-59	Third year	Rs. 306 lakhs (budget)

TABLE III

Sl. No.	*District*	*As per 1951 census book*			*Electrified as no 1-4-1958.*					
		Towns	*Revenue villages*	*Total*	*Towns*	*Revenue villages*	*Hamlets*		*Total*	*Total*
							Whose main villages are not electrified	*Whose main villages are electrified*		
1.	Madras	1	..	1	1	..	..	..	..	1
2.	Chingleput	20	2034	2054	19	674	13	221	224	917
3.	Coimbatore	22	941	963	22	455	105	821	926	1403
4.	Kanyakumari	20	1065	1085	17	191	5	56	61	269
5.	Madurai	26	1147	1173	26	303	41	248	289	618
6.	Nilgiris	4	47	51	4	33	2	239	241	278
7.	North Arcot	22	1854	1876	22	479	21	244	265	766
8.	Ramanathapuram	33	3710	3743	31	247	37	174	211	489
9.	Salem	19	1877	1896	19	234	44	119	163	416
10.	South Arcot	18	2256	2274	15	131	4	55	59	205
11.	Tanjore	29	2393	2422	28	314	49	62	111	453
12.	Tiruchirapalli	32	1524	1556	24	198	41	80	121	345
13.	Tirunelveli	49	1063	1112	40	243	43	157	200	483
		295	19911	20206	268	3502	405	2466	2871	6641

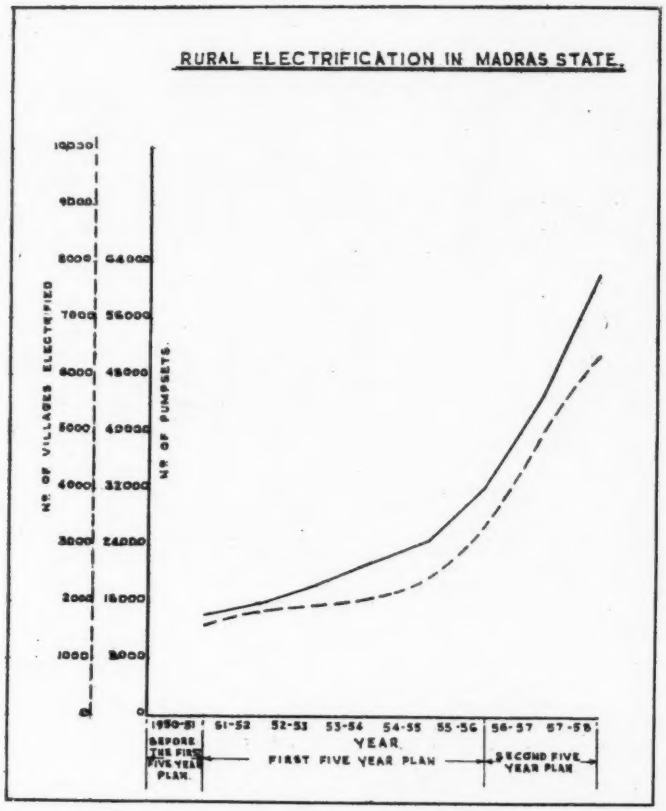
It will be seen from the table that 91% of the towns and 19.6% of the revenue villages as per 1951 census have been electrified apart from 2466 hamlets.

At the end of the first plan period only 7,400 villages and towns or 1.33% of the 5,61,107 villages and towns in the Indian union had the benefits of electricity.

Expenditure : The expenditure in respect of rural electrification during the second Plan period is given in the Table IV.

Agricultural Development : At present, electricity is used in villages, mainly for lift irrigation. Nearly 70% of the power consumed in villages or about 19% of the total consumption in the State is used up by agricultural pumpsets. There are at present nearly 70,000 pumpsets in the State using power from the Grid. The increased use of electricity for pumpsets can be seen from the graph on the next page.

With the redoubling of the target in respect of villages to be electrified to 1,000 the target of con-



necting up 6,000 pumpsets per annum during the second Plan period was revised to 10,000. The achievements during the first two years of the Plan period are given below :

1956-57	12,553
1957-58	17,388

In respect of utilisation of power for irrigation purposes, Madras State ranks first by way of consumers, consumption and connected load.

Table V gives figures regarding the use of electricity in agriculture in Madras State.

TABLE V.

1. No. of agricultural services to the end of 1957-58.	62,561
2. Average unit capacity of the pump	5.6 H.P.
3. Acreage irrigated by one pump (average)	6.7 acres.
4. Yield of food grain, in a year per pump	3 to 4.5 tons
5. Pump lift range	10 ft. to 110 ft.
6. Total connected load of pumping installation at the end of 57-58	2,62,000 kW. (Approximate)
7. Power consumed by electric pumps alone in 1957-58	214 million units (Appx.)
8. Consumption of pumping load to the total consumption of energy in the State	19%
9. Consumption of power for irrigation per acre of land	800 units.
10. Cost for the above power	Rs. 40/-

Rural Industries

Out of about 14,000 industrial services in the State, about 5600 are in rural areas. The total connected load is about 30 mW for the rural industries. In view of the increased developmental activities, during the Plan period, the demand due to these industries is expected to increase by about 5 to 6 mW annually.

Difficulties encountered

Supports : In view of the stringent foreign exchange situation and scarcity of steel prevalent in this country and the world over, steel supports are not available to meet the requirements. R. C. C. and wood poles are now being used extensively and steel supports conserved for fabrication of special structures. The R.C.C. poles are cast at a number of centres all over the State in standard lengths of 24 feet, 27 feet and 30 feet for use as L.T. and H.T. line supports. During 1957-58 about 45,000 poles of different sizes were manufactured in the various centres. Wood poles to the extent available are used in dry locations free from water and excessive moisture. The various species of wood poles used are teak, palmyrah, bluegum, pine etc.

Cross Arm : Though steel cross arms are generally used for both L.T. and H.T. lines, wood cross arms for wood poles and R.C.C. cross arms for R.C.C. poles are also used to effect economy and conserve steel.

Conductors and Insulators : All the requirements of conductors, L.T. insulators and a good proportion of 11 kV insulators are purchased from indigenous sources 22 kV insulators are however being imported as no suitable offers are forthcoming from indigenous manufacturers.

Single phase distribution : With the completion of electrification of most of the major villages near the secondary transmission lines, the Board is faced with the problem of extending supply to remote villages with only lighting load potentiality. In such cases it is planned to develop single phase distribution with single phase distribution transformers of 15 kVA capacity. Single phase 11 kV or 22 kV lines are now being constructed and the voltage stepped down to 237 volts by means of 11 kV/ 237 V or 22 kV/237 V single phase transformers. The outgoing L.T. line will be a single phase two wire distribution line.

Subsidy for Rural Electrification in Madras State

In the Madras State a rural extension is adjudged to be remunerative if the annual revenue over a ten year period is at least 10% of the capital cost of the

extension. It was found that such an extension when added on to the existing operating system had not affected, the financial sources of the system to below its interest earning level. With the present day increased cost for materials and equipments it is found that the working expenses amount to actually 18.2%.

If the addition of a rural extension should not adversely affect the present position of self remunerative aspect, the new extension should therefore give an annual return of at least 18% on the capital cost. The present figure of 10% return for considering an extension remunerative is obviously inadequate. Even to get this 10% estimated return, it is more often necessary to obtain special minimum guarantee from the consumers and this has been at present limited to Rs. 50/HP/per year. The need for asking for special guarantee has, in a way, restricted rural development in backward areas though most of the applicants are willing to pay the guarantee in a number of cases, with a view to get power for agricultural purposes. It is thus evident that with the existing tariffs, rural extension schemes cannot be self-sufficient and cannot be formulated without a subsidy. This subsidy can be in the form of (1) an outright grant to meet the capital either in full or part or (2) an interest free loan to meet the capital either full or in part or (3) an annual subsidy to meet the short fall of revenue required to cover the working expenses including interest.

The Government of India have been examining this question some time past and have constituted a Study group. The Study group have recommended that interest free loans for a period of five years upto 25% of the capital outlay on rural electrification may be made available to the States. The recent Irrigation and Power Seminar held at Srinagar (June 1958) considered the recommendation of the Study group and felt that the financial assistance proposed by the Study group would not achieve the results desired.

However they resolved to give a fair trial and stressed the Government of India to sanction the same early in order to enable the States to expeditiously implement their projected schemes. If the loan is made available, the benefits of electricity can be extended to about 1200 villages in Madras State for which schemes were formulated and found to be unremunerative.

Electrification of Harijan Colony

It has been decided as the policy of the Board that for all new schemes the Panchayat Board should be persuaded to include at least a few street lights in the Harijan colony of each village. In respect of villages already having supply and in which the Harijan Colony do not derive the benefits, it was estimated that a total sum of Rs. 15 lakhs would be required to extend the benefits. Commencing from 1957-58 the Government of Madras are diverting Rs. 1.5 lakhs per annum from the Harijan Welfare fund as grant in aid to the Electricity Board to extend electricity to their streets as a first step to improve their living conditions.

Conclusion

Utmost economy is adopted to extend electricity to the rural areas and constant efforts are being made to reduce the cost of these extensions. Some of the provisions of the Indian Electricity Rules have been partially relaxed in the design and construction of rural lines with a view to effect economy consistent with reasonable safety and case of operation and maintenance.

It is our intention to extend electricity to all villages in the State and electrify each home in every village in as short a time as possible.

Continued from page 13

New Power Schemes in Madras State

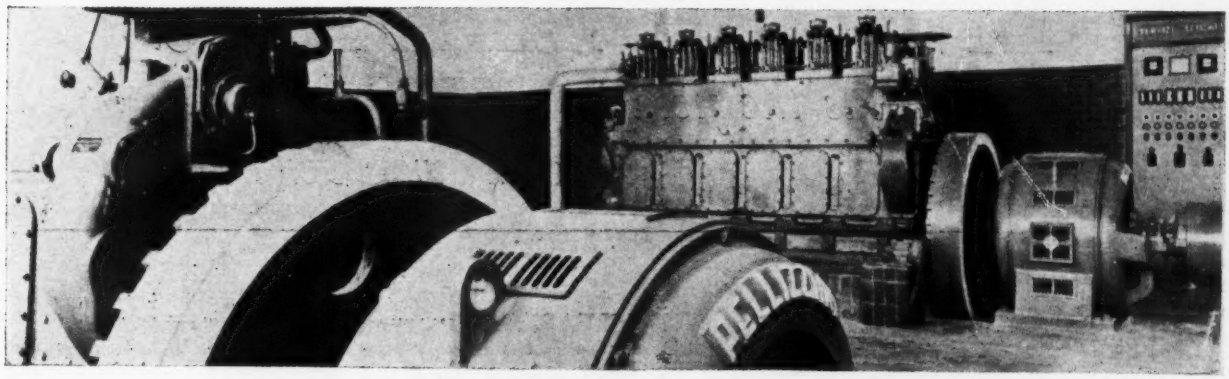
B. Under Construction :		
Hydro:		
1. Periyar ..	105,000	140,000
2. Kundah (Initial phase)	180,000	235,000
	285,000	375,000
C. Schemes Already Investigated:		
Hydro:		
1. Mettur Tunnel Scheme	200,000	200,000
2. Kumbar-Amaravathy Hydro Electric Scheme	20,000	20,000
	220,000	220,000
D. Bulk Supply Purchase:		
Hydro Power from Kerala State (As at present)	5,000	
Thermal power from Neyveli Thermal Station (by 1961)	200,000	
E. Schemes Under Investigation:	Continous power output in kW.	
1. Kundah (Ultimate phase)		67,000
2. Palar Porandalar		20,000
3. Coonoor—Kateri		52,000

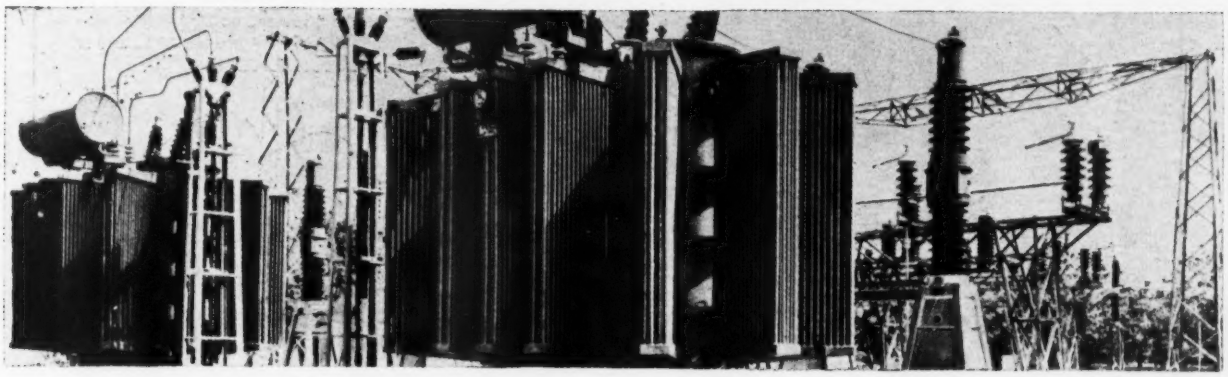
Note—Inter-State schemes have not been included as the negotiations between the various Governments are still under progress.

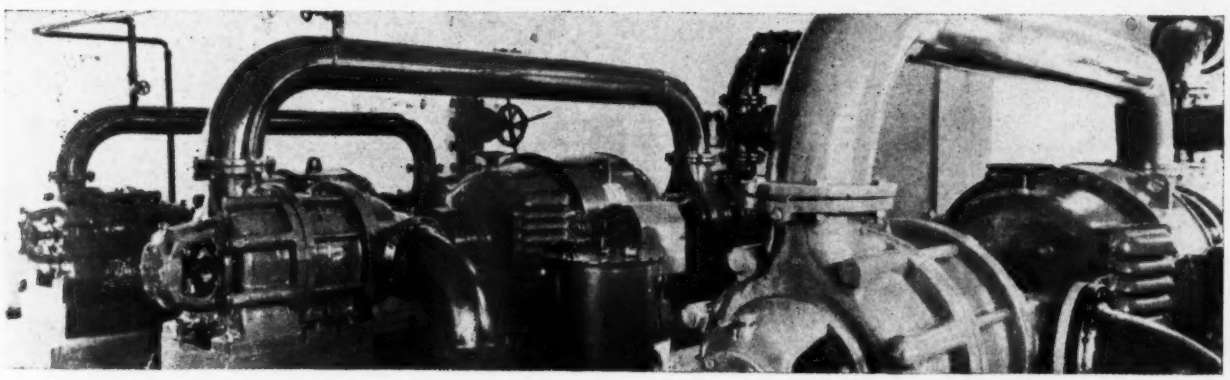
Interstate Schemes

It could be seen from the above that there are not many schemes within the State for hydro-electric development. Even those that are investigated can add only about 350 M.W. which is very meagre compared to the needs of the State. Of course, there are a number of schemes of inter-State nature which can meet both the irrigation and power needs of Madras State. To investigate them in detail we need the concurrence of the neighbouring States.

Negotiations are already taking place at Government level for taking up a few schemes but it may take considerable time before an agreement is reached. The Government of India in the meanwhile are considering the introduction of a bill in the Parliament which would give them powers for the speedy development of such schemes. Pending these, the State Electricity Board may have to resort to nuclear generation to meet the ever-increasing demand in the State and Madras State has a very strong case for a nuclear station in the third Plan period.







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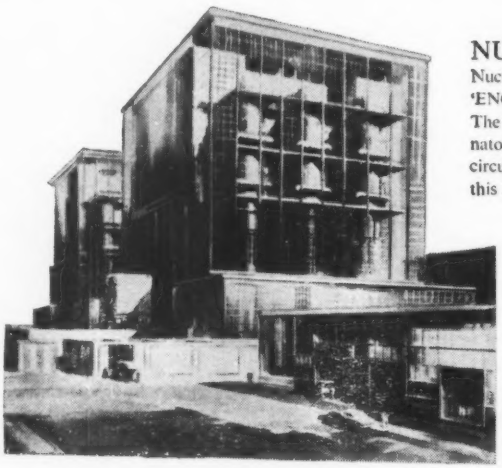
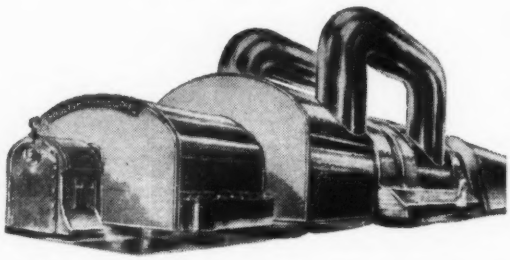
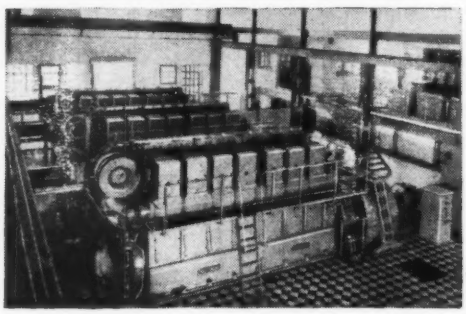


NUCLEAR. The first 500 MW Atomic Power Station (the world's largest Nuclear station) is under construction at Hinkley Point, U. K., by the 'ENGLISH ELECTRIC'—Babcock & Wilcox—Taylor Woodrow Consortium. The English Electric Company is supplying six main 93.5 MW Turbo-Alternator Sets, three 33 MW Variable Speed Turbo-Alternator Sets and a fifteen-circuit 275 kV duplicate Busbar Switching Station. The Reactors to be used at this Power Station will be of 'ENGLISH ELECTRIC' design.



STEAM. One of five 200 MW Steam Turbo-Alternators which the Company is supplying for the High Marnham Power Station, U. K. Early this year the Company received an order for two 275 MW Steam Turbo-Alternators for the New Blyth Power Station, U. K., and the sets are the two largest in-line turbo-alternators of their kind (50 cycles) in the world.

HYDRO. One of two 37.5 MW Water Turbine Generating Sets installed at Hirakud Power Station, Orissa. In the past 10 years the Company has supplied the entire plant for four major hydro-electric stations in India—Radhanagari, Nizamsagar, Sarda and Sengulam, and is manufacturing five—50 MW Water Turbine Generating Sets for the Rihand Power Station, U. P.



DIESEL. Three 'English Electric' Diesel Alternator Sets installed at Saateni Power Station, Zanzibar. The total output of the engines is 3,936 B.H.P. at 375 r.p.m. and the Station supplies the Island with a large part of its electricity.

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EEC-6

New Power Schemes in Madras State

By V. P. APPADURAI

Resources

The Madras State has no oil deposits. Until recently it was believed that it had no coal deposits either. Only a few decades back, lignite (brown coal) was located near Neyveli in the South Arcot district about 120 miles south of Madras City. The power development in the earlier years was therefore mainly confined to the hydro potentiality of the State.

There is a fair number of water power sites in the State but the total potential hydro power is small compared to those in other States like Punjab, Uttar Pradesh or Bengal. The sites are mostly in the Western Ghats especially in the Nilgris and Palni ranges. A close estimate of the available power has not yet been made. Hydro electric surveys and hydrometric works over several basins are still in progress. A rough estimate indicates that about a million kilowatt can be developed in the Madras State. Almost all the rivers of the State have small dry weather flow and hence the hydro schemes in the State involve storages.

Most of the sites with large and economic power potential have already been investigated and developed. With the demand of the grid continually on the increase, new power sites are being explored.

Administration

The investigation works were formerly carried out by two executive engineers one for hydro metric surveys and the other for hydro electric surveys. In view of the need to have sufficient number of schemes investigated and their reports approved by the Planning Commission well in time for executionduring the third Plan period, a new circle exclusively for the investigation works has since been formed in line with the policy enunciated by the Planning Commission. The circle, as desired by them, is functioning under the direct guidance of the Chief Engineer for Electricity.

Second Plan Outlay

A sum of Rs. 19.5 lakhs has been included for the investigation of new schemes in the State during the second Plan period.

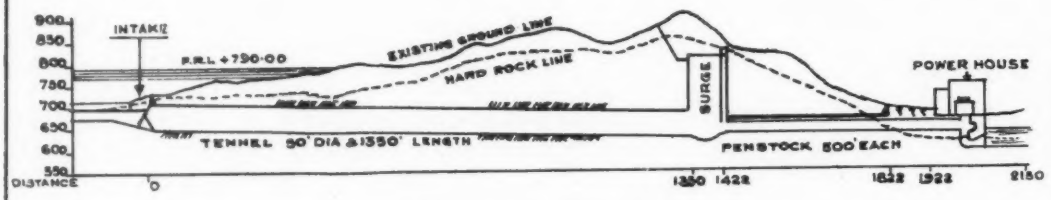
Progress

During the Plan period, the field investigations of the Mettur tunnel scheme, Kumbar-Amaravathy Hydro Electric Scheme and Palar-Porandalar Hydro Electric scheme have been completed. The investigations of Kundah ultimate phase is now in progress. The scheme report for the Mettur tunnel scheme has already been forwarded to the Government of India and is now under scrutiny by the Projects Advisory committee constituted by the Planning Commission. The scheme report for the Kumbar-Amaravathy and Palar-Porandalar Hydro Electric Schemes are under finalisation.

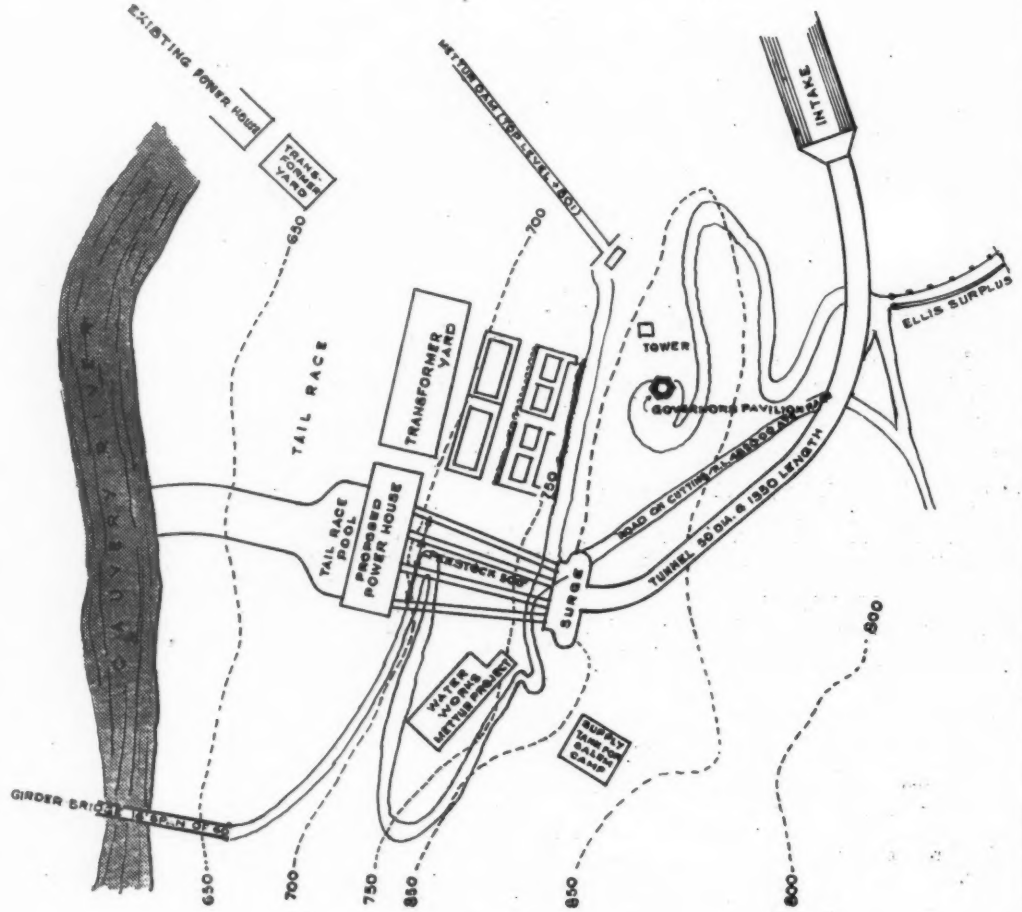
The details of the schemes are given below.

Mettur Tunnel Scheme

In this scheme it is proposed to harness the large quantity of water that is being passed from the Mettur reservoir to the Cauvery river during the irrigation season each year, for producing seasonal power and feeding into the Madras Power Grid. The Mettur Dam has got two sets of irrigation sluices, the high level and the low level, consisting of 5 vents of $14' \times 7'$ each through which irrigation requirements below the dam are discharged. No electric power is now being generated using the discharges from the irrigation sluices. The existing four hydro electric pipes have a diameter of 8.5 ft. and can discharge a maximum of 1250 cusecs for power purposes under a varying head of 60′ to 160′. From the irrigation discharges, it is seen that the ratio between the quantity of water passing through the hydro electric pipes compared to that passing through irrigation sluices during the irrigation period, lasting about 7 months in a year is about 1:5 (i.e.) a large quantity of water, about 5 times the quantity now producing power at Mettur, passes from the lake to the river without any power being produced from it. In the present scheme it is proposed to use all the water let down for the irrigation of the Cauvery delta for purposes of power generation.



PROFILE OF THE SCHEME



SCHEME LAY-OUT

METTUR TUNNEL SCHEME

Several alternatives were considered for seasonal power generation and it was finally decided that a tunnel scheme without interfering with the existing irrigation sluices will be the most suitable. It is proposed to bore a tunnel about 50 feet diameter on the left flank capable of discharging about 20,000 cusecs. There will be 4 penstock pipes taking off from the surge shaft at the end of the tunnel, each feeding a 50 M.W. generator set. The Power House will be far away from the dam structure and interference with the existing dam structures will be reduced to the minimum and practically all the water let down for irrigation requirements can be utilised for power generation. The total installed capacity will be 200 M.W. The head will vary between 60′ and 160′. The power generated will be fed into the existing grid through a 230 kV transmission line linking at Salem. This seasonal power will be firmed up by Kundah, Pykara and Moyar Hydro Electric stations and Madras, Madura and Neyveli thermal stations.

The scheme is estimated to cost Rs. 13.32 crores.

Kumbar-Amaravathi Hydro Electric Scheme

The Scheme is situated in the Palni Hills.

It is proposed to have two storages on the upper reaches of the Kumbar river and a pick-up reservoir across Kumbar with F. R. L. + 5060. The Power house will be located at + 2100 elevation. The maximum gross head available for power development is 2960 ft. The peak out put in an average year with 60% L. F. will be about 16,700 kW. and the installed capacity will be 20,000 kW.

Palar-Porandalar Hydro Electric Scheme

The two rivers Porandalar and Palar, with their source near Kodaikanal, drain the northern slopes of Palni Hills to join each other in the plains near Palni town to form the Shunmuga Nadi, a tributary of Amaravathi.

The river Porandalar has a catchment area of 43 sq. miles above the pickup reservoir site at about elevation + 3200. The power house will be located at + 1200 at the foot of the hills.

The Palar has a catchment of about 27.74 sq. miles above the pickup reservoir site with bed level at about + 3600. The power house will be located at + 1300, at the foot of the gorge and on the left bank of the river.

The continuous power that can be generated in both the power houses is expected to be about 20,000 kW.

Kundah (ultimate phase)

The ultimate phase of Kundah extensions, will be in continuation of the present scheme (initial phase) under execution. The scheme in brief is to add a third unit in Power House-I, a fifth unit in Power House-II and the construction of a third Power House. The ultimate stage extensions will be investigated and got sanctioned before the completion of the initial phase in order that the execution of the ultimate phase may be taken up, as a continuation of the initial phase.

The ultimate extensions comprise the following detailed works.

1. Storages on the east and west Varahapallam streams.

2. Interconnecting and diversion tunnels leading Varahapallam waters to Emerald-Avalanche reservoirs.

3. Diversion of western catchment waters into Porthimund reservoir and into the Avalanche-Emerald reservoirs.

4. Adding one more penstock and one more unit respectively by in the power houses 1 & 2.

5. Dam across Pegumbahalla forming forebay for power house No. 3.

6. Pressure tunnel from forebay to surge shaft.

7. Underground penstocks, power station No. 3 and tail race for this power house with a gross head of 1,555 ft.

Besides the above the falls between (*i*) Upper Bhavani storage and Avalanche-Emerald reservoir (*ii*) Porthimund and Avalanche-Emerald and (*iii*) Varahapallam storages and Avalanche-Emerald reservoirs will also be considered for power development at a later stage depending on their feasibility and economy.

The extra-continuous power that can be generated at power house No. 1 and 2 by the additions contemplated is 5.64 M.W. and 9.85 M.W. respectively. The increase by way of installed capacity in both the power houses will be 55,000 kW. The extra continuous power that can be generated at power house 3 under Stage IV is 51. 5. M.W. Thus, the total extra-continuous power that can be got from these 3 power houses with the completion of the ultimate phase as contemplated above will be 66. 999 M.W. or 67 M. W.

The investigations of the scheme have just commenced.

Power Potential of Madras State

The power potential of Madras State under different heads are given in the table below.

TABLE I

Power Potential of Madras State

Sl. No.	*Name of Power Station*	*Installed Capacity in kW.*	
		Present	*Ultimate*
A. EXISTING:			
Hydro:			
1.	Pykara ..	70,200	73,200
2.	Mettur ..	40,000	40,000
3.	Papanasam ..	28,000	32,000
4.	Moyar ..	36,000	36,000
Thermal:			
5.	Madurai ..	14,000	14,000
6.	Madras ..	98,500	98,500
		286,700	293,700

[*Continued on page* 10

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Kundah Hydro-Electric Project

By V. P. APPADORAI

The Kundah hydro-electric project is the sixth hydro electric project undertaken by the Department. It is the most important power project of the second Plan now under execution and is the biggest scheme so far launched to develop the available power resources of the State

Location

The plan and profile of the scheme is on the following page. Kundah basin is located in the western catchments between latitude 11°10′ and 11°25′ north and longitude 76°30′ and 76°48′ east. The basin is situated to the south-east of the Pykara basin in the Nilgiris. Two streams, the Avalanche and the Emerald, rising amidst the group of high peaks, Devabetta, Karaikada, Koulinbetta and Porthimund, all over 8,000 ft. in altitude, combine to form the Kundah river. After the confluence, the river takes a south-easterly course and is joined by the Sillahalla near Mandanai at an altitude of 6,000 ft. The Kundah has then a fall of about 200 ft. and runs in cascades for about 2,000 ft. to reach the bridge near Kundah village where it is joined by the Kanarahalla stream. Below the bridge the river runs in cascades till it reaches a level of 2,100 ft. above M. S. L. where it is joined by the Pegumbahalla stream. Beyond that confluence it runs in rapids for about a mile and half and later, in an easy gradient, down to its junction with the Bhavani at an altitude of 1,340 ft.

Proposals

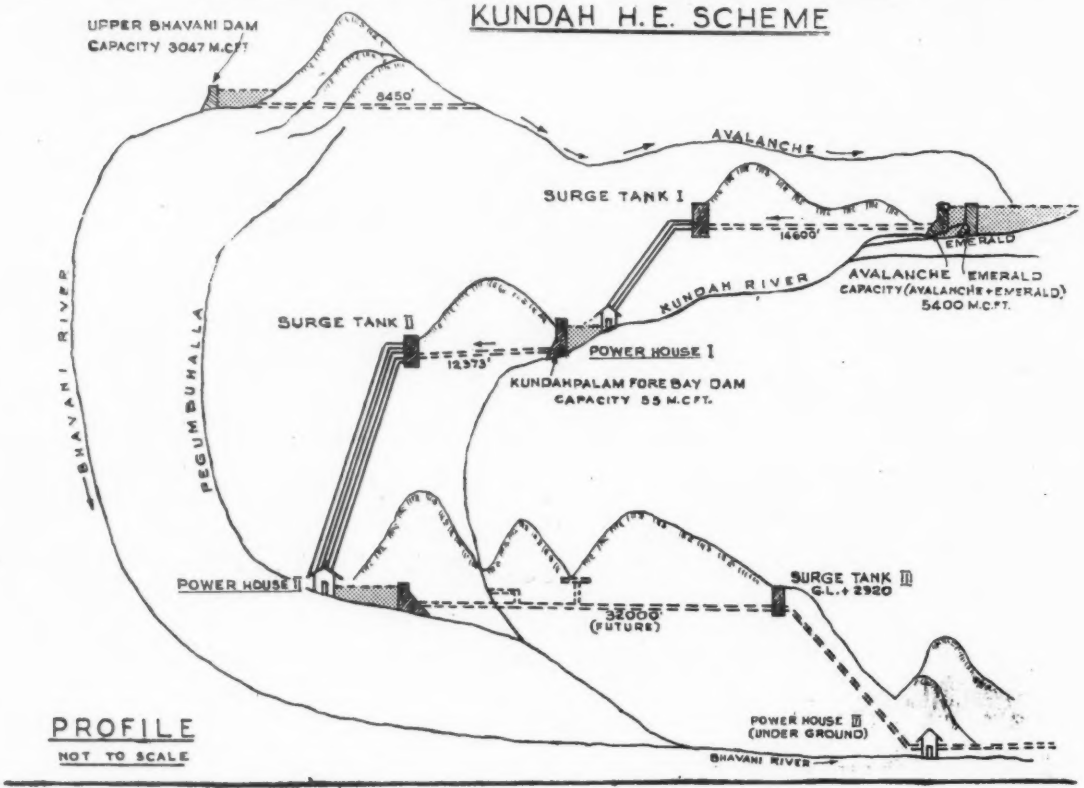
The development of the Kundah basin in the Nilgiris hills is proposed to be taken up in two phases with three power stations. The initial phase involving the construction of two power houses only has been investigated and is programmed to be taken up during the second Plan period.

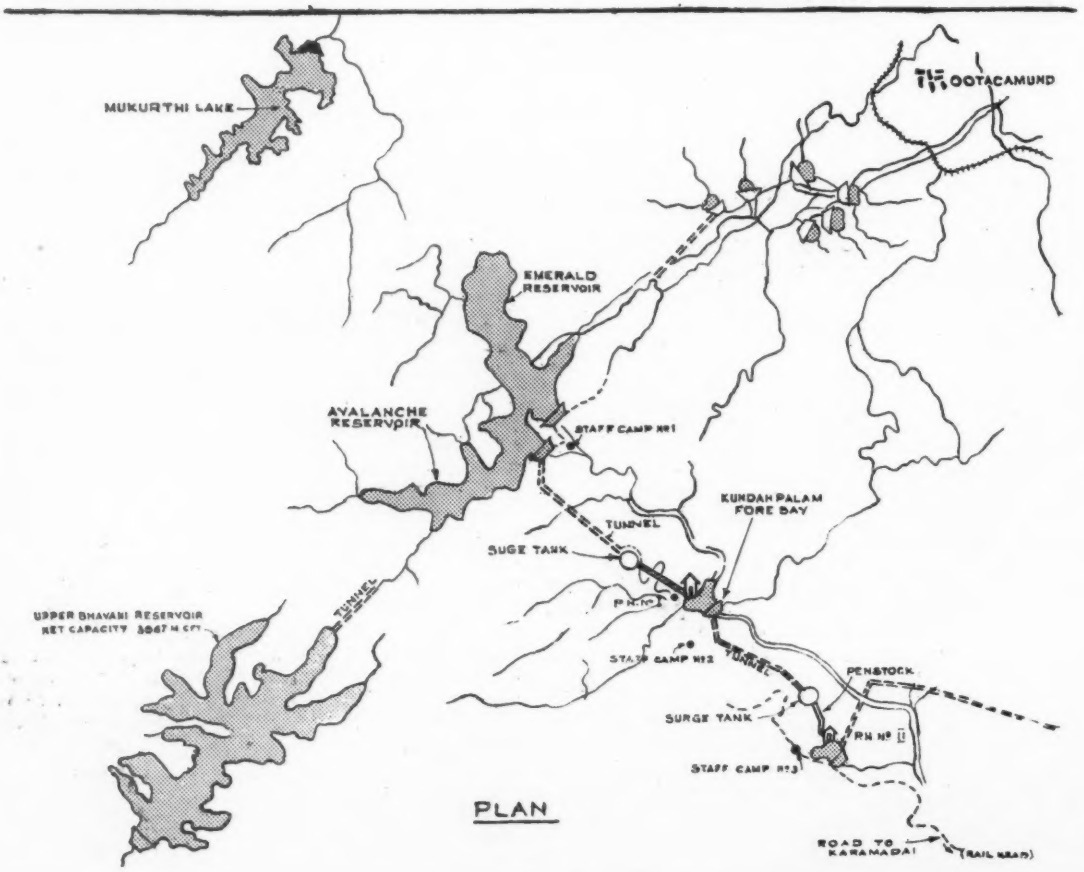
In the initial phase it is proposed to build four dams (including the forebay dam), two power tunnels, two inter-connecting tunnels, two sets of penstocks and two power stations.

The first power station will be located on the right bank of Kundah river and the second power station on the left bank of Pegumbahalla stream about a mile and half above its confluence with the Kundah river.

The scheme was investigated in detail during the first Plan period itself. A scheme report was submitted to the Government and the Central Water and Power Commission during January, 1952. The scheme was revised after scrutiny by the Central Water and Power Commission. A revised scheme incorporating the suggestions of Mr. Monkhouse, an expert attached to the Central Water and Power Commission was sent to Government during February, 1954. This was scrutinised by the Central Water and Power Commission as well as the Planning Commission and the Planning Commission were kind enough to agree to commence the preliminary works connected with the scheme during the first Plan period itself. The scheme was sanctioned by the Government during September, 1955. It is estimated to cost Rs. 35.44 crores for the initial phase now under execution.

On account of the difficult foreign exchange position during the second Plan period, this scheme was included among other schemes for aid from the Canadian Government under the Colombo Plan. During December, 1955 a team of Canadian experts inspected the project site and gave a favourable report to their Government on technical soundness of the scheme. The Government of India then sent a delegation headed by Sri C. V. Narasimhan, I. C. S., the then Joint Secretary of the Ministry of Finance, together with the State Chief Enginner ofr Electricity Sri V. P. Appadurai, to negotiate the terms of the aid etc. during May, 1956. The mission proved very successful. The Canadian Government who originally contemplated to give about 14 million dollars as aid to the scheme finally agreed to allot about 20 million dollars worth of machinery to the Kundah Project. The Chief Engineer for Electricity returned to India during June, 1956, after finalising the terms of the agreement etc. This scheme was then inaugurated on 29-6-1956 by the Union Minister for Finance, Sri C. D. Deshmukh.


KUNDAH H.E. SCHEME
UPPER BHAVANI DAM
CAPACITY 3047 M.CFT
8450'
AVALANCHE
SURGE TANK I
14600'
EMERALD
AVALANCHE EMERALD
CAPACITY (AVALANCHE+EMERALD)
5400 M.C.FT.
KUNDAH RIVER
SURGE TANK II
12373'
POWER HOUSE I
KUNDAHPALAM FORE BAY DAM
CAPACITY 55 M.C.FT.
BHAVANI RIVER
PEGUMBUHALLA
POWER HOUSE II
SURGE TANK III
G.L.+2920
32000
(FUTURE)
POWER HOUSE III
(UNDER GROUND)
BHAVANI RIVER
PROFILE
NOT TO SCALE

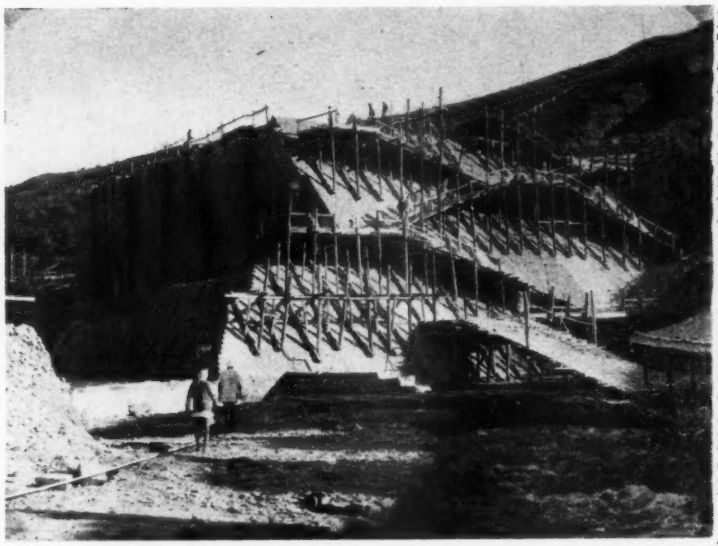

MUKURTHI LAKE
OOTACAMUND
EMERALD RESERVOIR
AVALANCHE RESERVOIR
STAFF CAMP NO1
KUNDAH PALAM FORE BAY
TUNNEL
SUGE TANK
P.H. No I
UPPER BHAVANI RESERVOIR
NET CAPACITY 3047 M.CFT
TUNNEL
STAFF CAMP NO2
TUNNEL
PENSTOCK
SURGE TANK
P.H. No II
STAFF CAMP NO3
PLAN
ROAD TO KARAMADAI
(RAIL HEAD)

SALIENT FEATURES OF THE SCHEME

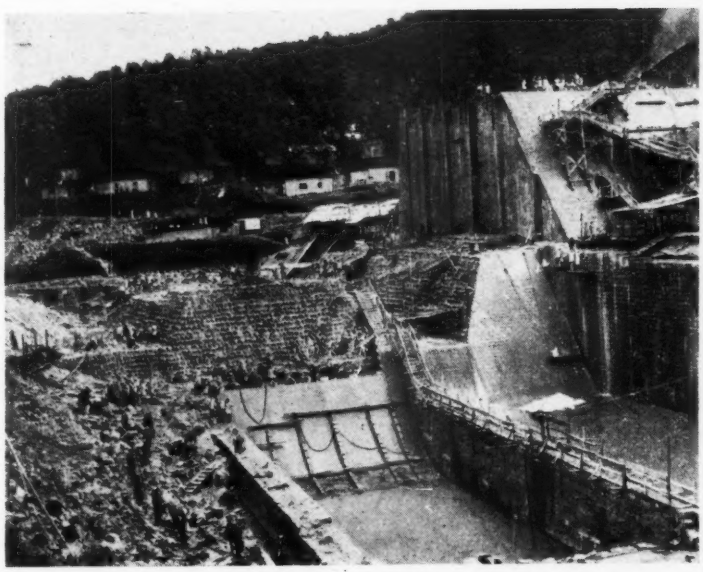
Emerald and Avalanche Dams with the Interconnected Tunnel

The Emerald and Avalanche Dams are being built across the two arms of the Kundah river, Emerald and Avalanche streams. They are of stone masonry—gravity type—providing a total useful storage of 5,400 million c. ft. The Avalanche Dam is about 186 ft. high and 1,200 ft. long at the top of the dam. The Emerald Dam is 212 ft. high and 1,060 ft. long at the top. Both the reservoirs have a catchment area of about 22.6 square miles. The Emerald Dam is of non-overflow type with suitable scour vent of 7′/5′ size. The Avalanche Dam is of spillway type. It has a spillway of about 95 ft. wide and a scour vent of 7′/5′. The main power tunnel for Power House No. 1 takes off from this Dam. An intake of 10 ft. diameter is provided in the Dam. Both the reservoirs formed will be inter-connected by a tunnel of horse-shoe size (9′7½″×9′7½″) with a discharge capacity of 750 cusecs.

Emerald Dam



Avalanche Dam



Upper Bhavani Dam and Tunnel

This Dam will be built across the Bhavani river at its upper reaches. The Dam will be 1,030 ft. long at its top, 246. high and 20 ft. wide at the top. The location of the Dam has just been fixed up. The storage of the reservoir formed is 3,047 m. c. ft. with a catchment area of 12.8 sq. miles. The reservoir is connected to the Avalanche reservoir through a tunnel of 8450 ft. long.

Tunnel I

The water from the Emerald and Avalanche reservoir is taken through a tunnel with a horse shoe section 9′ 7½″×9′ 7½″. The tunnel is 15,500 ft. long with a discharge capacity of 750 cusecs. The work is being executed on contract by M/s. Gannon and Dunkerly & Co., Ltd., Madras. The total cost of the contract works out to Rs. 85.65 lakhs.

In view of the long length of the tunnel, excavation is simultaneously done at about eight faces. Two shafts, one near Lawrence stream and other near Gayakandi stream at chainages 3100 and 6400 have been sunk. In addition one addit at chaninage 10640 has also been formed. At present works are in progress at six faces simultaneously.

The tunnel commences with a 10′0″ diameter steel pipe for a distance of 505 ft. and then the tunnel is excavated in rock. Concrete lining with suitable reinforcements will be made for a length of about 7400 ft. Balance will be a concrete lined one without reinforcement.

Surge Shaft I

The tunnel ends in a surge shaft which will be cut 35′ ft. in earth and balance in rock. The surge shaft will be 28 ft. in diameter in earth and 25 ft. in diameter in rock and 275 ft. deep. The excavation commenced during November, 1956. The walls of the surge shaft will be lined by R. C. C. with 5/8″ and 1″ diameter rods.

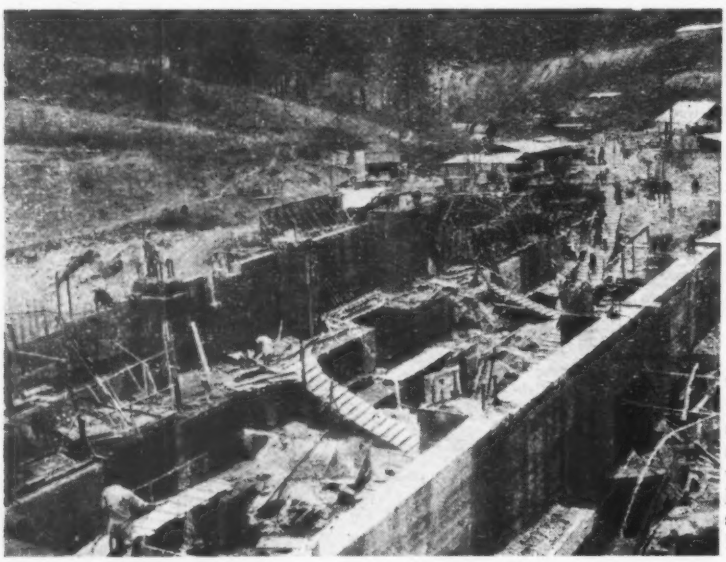
Tunnel I. Drilling work in progress

Penstock I

The water is taken from the surge shaft through a steel pipe of 9′0″ diameter, for a length of about 800′ embedded in a tunnel, At the end of these pipes, there will be a trifurcating manifold 108″/63″×63″ with three 63″ butter-fly valves, 18″ air-valves and the necessary metering equipment, stationed in a valve house.

Two steel penstock pipes of diameter ranging from 63″ to 51″ and thickness 9/16″ to 11/16″ between anchor 7 to 6 and 5/16″ to 1/2″ between anchors 6 to terminal anchor carry the water from the Valve House to the Power House. The pipes are made out of special type of high tensile steel—U.S.T.-I. steel—with a yield strength of 90,000 lbs. per sq. inch. This is the first time, such a type of steel is used in this State. This has three times the yield strength of ordinary steel and readily weldable without preheating or stress relieving, with an atmospheric corrosive resistance of 4 times that much of carbon steel. The total length of the pipe line works out to about 3,300 ft. The pipes will be carried on saddles one for each piece. High pressure valves will be provided for each of the penstock pipes near the Power House end. Two penstocks are laid initially feeding two units and a third one will be added later. The pipes are supplied by M/s. Davie Ship Building Co., Canada.

Power House I.



Power House I

The Power House building will be of structural steel frame and stone masonry walls. The building will be 202 ft. long, 78 ft. wide and about 50 ft. high from the generator floor level. This is designed to accommodate all the three generating units of the ultimate stage of development.

Power Plant I

The power plant will consist of two multiple jet impulse type turbines supplied by Dominion Engineering Co. of Canada rated at 28750 H.P., 428 RPM each coupled to 20,000 kW (24000 kVA), 11 kV 50 cycles 3 phase generators of Canadian Westing house make.

Transformer Yard

The transformer yard will be close to the Power Station. There will be six 8000 kVA 11 kV/110 kV single phase tansformers for stepping up the voltage to 110 kV. The transformers are of Canadian General Electric make. Provisions will be made for 3 more single phase transformers to be installed at a later date. From the yard, D. C. 110 kV line takes off to Power House No. II.

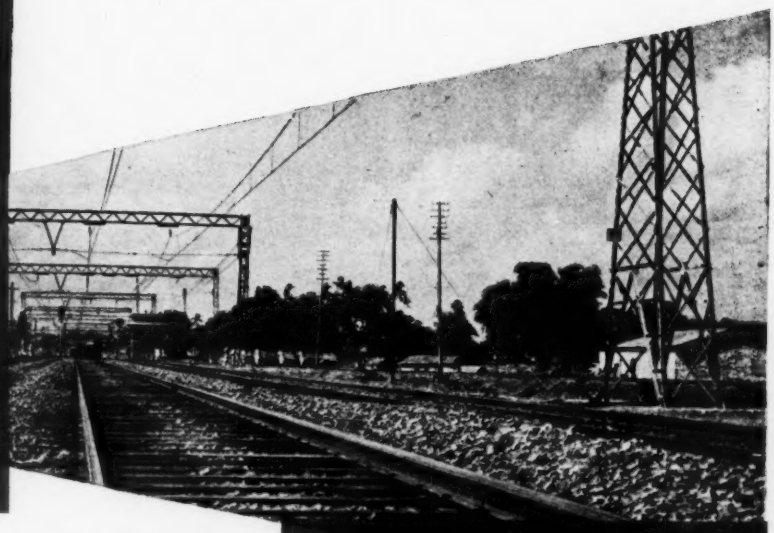
Kundah Palam Dam

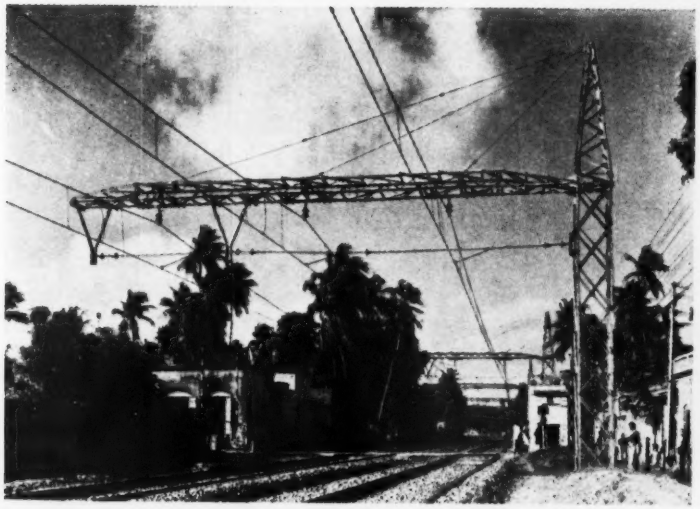
The tail race water from Power House I will drain in the Kundah river near the Kundah Palam village, where it is joined by the Kanarihalla stream. A forebay Dam—Kundah Palam Dam—of masonry gravity type is being constructed to form a small forebay with 55 m.c ft. storage capacity. The dam is 560 ft. long and 15 ft. wide at top. The height of the dam is about 95 ft. It has a spillway of 95 ft. long between chainages 140 and 235. A scour vent of 12′×8′ is provided in the dam with a regular and emergency gates. An intake for Tunnel II of 11′-3″ steel pipe is provided with an emergency and regular gates at chainage 350 ft.

Tunnel II

The water from the forebay is taken through another tunnel for a distance of about 12400 ft. The tunnel is of horse shoe shape of 11′×11′ with a maximum discharge capacity of 1000 cusecs. The work has been given on contract to M/s. Hind Constructions Ltd. for a sum of Rs. 54.20 lakhs during July, 1957.

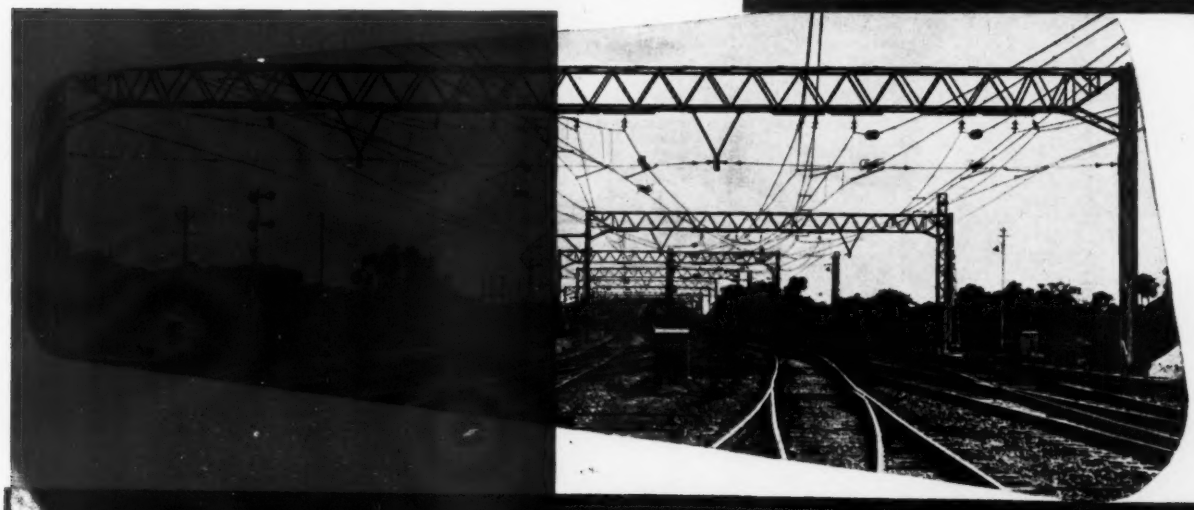
S.A.E.





S.A.E have been chosen to design, supply and erect the track structures and 3000V D.C. traction Overhead equipment for the Eastern Railway between Howrah – Bardwan and Sheorophulli – Tarakeswar because S.A.E's engineers are the most experienced in Railway Electrification.

The photos represent views of the sections Howrah-Bandel and Sheorophulli-Tarakeshwar electrified by us and already under service.



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Kundah Palem Forebay Dam

The tunnel commences from 11′ upstream of the central axis of the dam with an intake piece of 13′-8″ in length. Beyond this point, a steel lined tunnel of 11′-3″ dia. is taken for a length of 180′.

The tunnel throughout its length is lined with cement concrete of thickness varying from 8″ to 12″. In bad patches they are also reinforced with 5/8″ dia. rods wherever considered necessary.

The tunnel length is about 11553 ft. from the centre line of the dam to centre line of the surge shaft. The excavation work is now being carried out at 8 faces. There are two addits, one at chainage 1200 and other at chainage 5743. Between chainage 10686 and 11126 there is a low saddle and the tunnel does not have the required coverage of 120 ft. at this portion. Hence, it is proposed to have a steel pipe of 11′-3″ dia. embedded in rock in this low saddle For a length of 440 ft. the steel pipe will be encased in a bed of concrete. For 320 ft. it will be 11′-3″ steel pipe lined tunnel beyond which the tunnel will be reinforced.

Surge Shaft and Pipe Tunnel

Tunnel II ends in a surge shaft which is partially embedded in rock. The shaft is 40′ in diameter for a depth of 87′ from the top and then 25 ft. to the bed of the tunnel. The total depth of the shaft is 225 ft.

The water from the shaft is taken through R.C.C. tunnel of horse shoe shape of size 11′-0″ for a length of 750 ft. Beyond this pipe line tunnel of 10′-9″ is provided for a length of 70′. The manifold starts from here.

The manifold is of 10′-9″ internal diameter. It bifurcates into two pipes. Then one trifurcates into 3 of 4′9″ diameter pipes. The other bifurcates into 2 of 4′-9″ diameter pipes.

The water is then taken down through penstock pipes. Initially 4 pipes are laid and provision is made for the 5th one. The diameter of the penstocks varies from 4′-9″ to 3′9″ with their thickness ranging from 5/8′ at the top to 13/16″ near the terminal tower. The total length of each pipe works out to about 5,300 ft. of which the first 700 ft. is of A.S. T. M. Steel and the rest of special type U. S. 'T' I. Steel (High Tensile Steel).

Power House—II

The 4 pipes terminate themselves at the four turbines of 50,000 H. P. vertical multiple jet impulse wheels 428 RPM. of 35000 kW each capacity. The Power House is of structural steel frame and masonry walls and of size 302 ft. long and 78 ft. wide and about 50 ft. high above generator floor. This will ultimately house five 35,000 kW. generators.

Plant II and Transformer Yard

The generating machinery consists of four impulse type turbines of 50,000 H.P. each, of Dominion Engineering make each coupled with 35,000 kW. C. G. E. generators 3 phase 11 kV 50 cycles. Space has also been provided for the 5th unit in the Power House.

The tail race of the Power House drains in the Pegumbahalla stream. The transformer yard will be adjacent to the Power Station. On account of the difficult terrain, and in order to avoid excessive rock cutting the transformer yard will be stationed at two levels. The yard will be divided into two sections, one for the 110 kV side and either for the 230 kV side. The 110 kV bays are adjacent to the Power House and the 230 kV bays are beyond the 110 kV portion.

In the 110 kV section, the yard will have four 42,000 kVA Power transformers 3 phase units of 11 kV/110 kV and nine 110 kV circuit breakers of 2500 MVA rupturing capacity. Provision has been made for the 5th transformer in this bay.

The lines from Kundah Power House I terminate in this bay. A double circuit 110 kV line takes off from this substation to Tudialur to link up with the grid, on the 110 kV side.

The 230 kV portion of the yard contains three 50,000 kVA 3 phase auto-transformers 110 kV/230

kV, one 230 kV 3 phase 3500 MVA circuit breaker and other equipments. From the 230 kV bay, one single circuit 230 kV line takes off to Salem. Provision has been made for another line from this yard at a later date under ultimate stage of development.

Transmission System

The transmission system covers the Coimbatore District, Salem District, South Arcot District and Chingleput District. The transmission system comprises 287 miles of 230 kV S. C. line with (42/0. 1376 Al + 7/0764 St) 795000 CM A. C. S. R. conductor and 30 miles of 110 kV D.C. line with 6/.2109 Al + 7/.0703 St. 266800 A.C.S.R. conductors.

Carrier communication and relaying will be provided on the 230 kV line. On the 110 kV lines carrier communication alone is provided.

Substations

The power will be stepped down to 110 kV at Salem and Villivakkam and fed into the 110 kV systems of the Substations and Grid. Additional transformers will be installed as follows:—

Salem: Two 50 MVA 230 kV/110kV auto-Transformers.

Villivakkam Two 50 MVA 230 kV/110 kV auto transformers.

For system stabilisation, a 25 MVAR synchronous, condenser will also be installed in the Villivakkam S. S. The Kundah Power Houses will also be interconnected with the existing grid at Thudiyalur.

Canadian Aid

We have been fortunate in getting the Canadian Aid for this scheme under Colombo Plan by way of machinery and materials. By an agreement signed at New Delhi on 29th December, 1956, the Government of Canada have agreed to give aid to the extent of 20 million dollars (about Rs. 10 crores). This aid was found to be not adequate to complete the transmission lines and complete the project in all respects. So the Government of Canada was approached for an additional aid of 5 million dollars to complete the project. The Canadian Government has generously agreed to give this additional amount and the total aid comes to about 12.5 crores of rupees. The aid has come as a great boon to us especially during these hard days of stringent foreign exchange situation.

Orders for most of the major equipments were placed in December, 1956. The construction machinery have already been received and are on use in the project. A major portion of the penstock pipes have already been received at site. The rest of the pipes have been shipped and are expected at site shortly. The structural steel for Power House building have been received and the structures are under erection. During last year, materials worth about Rs. 48 lakhs have been received from Canada. During the current year all the pipes and other materials costing about Rs. 622 lakhs would be received. Almost all the main equipment will be delivered at site as per schedule before the end of 1959.

Present Progress of Works

The works are in full swing at the three Dam sites, 2 Tunnels, 2 penstock slopes, 2 Power House sites etc. The excavations at the Dam sites are almost complete and masonry works are in good progress at the Avalanche, Emerald and Kundapalam Dam sites. The embedded parts for the scour vents are expected shortly and will be arranged to be installed in their respective locations.

In Tunnel I, about 8000 ft. of excavation has been done. At Tunnel II, about 3000 ft. of excavation is completed. Both the penstock slopes have been graded and foundations for anchors are being laid in Penstock I. The track line for Penstock I is completed and for II is in Progress.

The surge shaft excavation at I is over and at II is nearing completion. They are being lined up with concrete.

At Power House I the excavations for Power House structural foundations are over and the first stage concreting for Power House structures are in progress. At Power House II site, the excavation for machine foundations are nearing completion.

The low pressure pipes have been received at site and the penstocks have been shipped. Work on the 110 kV line is already in progress, and a major portion of the 110 kV line materials have been received.

Programme

The works are proceeding as per programme. The 1st unit is expected to be commissioned during April, 1960 and all the rest before the end of 1960.

This is a mammoth scheme undertaken for the first time in such an unprecedented scale in the history of the Department. Brisk activities can be witnessed simultaneously at all the workspots of the project. It is an ambitious scheme programmed for completion in a record time of four years. All the staff are putting forth their full efforts in order to achieve this target and show to their Canadian brother engineers how much the Madras Indian engineers can do after independance.

The scheme on completion will make available to the grid 1,80,000 kW of installed capacity. This will greatly relieve the power shortage now being experienced during summer in this part of the subcontinent.

Periyar Tunnel Works

By S. SUBRAMANIAM

The diversion tunnel constructed for Power development in the Periyar Hydro Electric Scheme commonly called the periyar tunnel for a discharge of 1600 cusecs, is the second medium size tunnel executed by the Madras Government Electricity Department after Machkund tunnels. This costs 34.5 lakhs, including surge shaft and pipe tunnel. Periyar lake water after emerging out of the irrigation tunnel is diverted through power tunnel, by construction of a small dam 400 feet, downstream taken to surge shaft and then through penstock to the Power House for generating power.

This tunnel is 3,992 ft. long completely concrete lined with 150.13 sq. ft. waterway and a total bed fall of 33.7 from forebay to surge shaft (slope 1/116.54) The tunnel has been bored through good rock and involves an excavation of 8,74,237 cft. of rock and 2,23,936 cft. of concrete lining. The maximum cover over the tunnel is 348 ft. with a minimum of 28 ft. The tunnel has three bends, (as shown in sketch figure 1).

The works connected with tunnel, surge shaft and pipe tunnel were entrusted to M/s Patel Engineering Company, Limited, their rates being lowest in the tenders. According to the conditions of the contract, Department had to provide :—

1. Access roads to work spots.
2. Services like electric power.
3. Water supply during irrigation tunnel closure period.
4. Magazine for storing explosives.
5. Medical aid and health measures.

Tunnelling works

General arrangements of work, in the first instance, were to tackle in three faces simultaneously in accordance with modern methods. The adit at about 1,100 ft. from the inlet provided two faces, with the third from the forebay dam. Later on to accelerate the progress, fourth face was made available at the surge shaft through a second adit. It was planned to cover maximum length through adit no.I. as it afforded greater facilities for disposal of muck and other movements of equipment. Accordingly, the adit tunnel was formed in 7/55 with a section of $14' \times 9'$ sufficient to accommodate double line traffic for locos and two. ventilation ducts of 20" diameter.

A second adit referred to above, of length 152.5 ft. shaft end $14' \times 9'$ section was formed with a grade of 1/112 merging at surge shaft at R.L.2705.

Power Tunnel Entry

Full face tunnelling was carried out in all the faces working in three shifts adopting normal round of 5 ft. As the excavation beyond pay-line was penalized by payment of Rs. 0-14-0 per cft., boring was done 3" inside the neat line of excavation and then the section was trimmed to the required profiles and grades.

Atlas and C.P.T. rock drills with penumatic pushers were used for drilling work. Drill steel used was 1½″ round in section and the chisel inset was provided with tungsten carbide tips. The sizes of rods used were 2′-7″, 5′-3″, 7′-10″ and 10′-6″ in length with 4¼″ and 3¼″ shanks. The average life of the bit was 350 ft. in micaceous rock and 500 ft. in sound rock. One item of operation which was very valuable is the practice of removing all drill steels and rock drills to field workshop between rounds. They were carefully checked, bits ground where necessary and thus the drilling cycle began with a complete set of drill rods of adequate lengths in such a condition as to minimise the last drilling time for interruptions due to either rock drills or drill rods.

Generally after experimentation 5′-0″ round were adopted for major portion of the tunnelling with modified burn cut as shown in figure 2. About 55 to 60 holes were drilled per round, 21 being above the axis level with the rest below. Five rock drills were used. The roof holes were drilled from a pipe timber platform rigged and fixed to the sides. Air pressure of 80 lbs. was obtainable at the end. 4″ victualic pipe with suitable manifolds were used for the air mains. Supply of air was from one 560 Cfm. and one 315 cfm. electrical compressors. The average drilling operation took 2 to 3 hours per round at Adit no. 1.

After drilling operation is completed the holes were cleaned with compressed air and loaded with gelegnite 75% to 80% strength (supplied by Imperial Chemical Industries) in sticks of 1″×4″ and 1″×8″ long. The charge used depended upon the length of hole. Holes were detonated with standard blasting delays from 0 to 4. The detonators were connected in series and the two open ends ware joined to shot firing cable, (two loads of 1/044 V.I.R. wire used in this tunnel), which is taken to the exploder and blasted. The exploder used was of *Bethoven* make. The drilling and blasting pattern thus developed were effective both in case of operation and ease with which resulting spoil could be handled by showels. The explosives ratio was found to be 12 lbs. per 100 cft. of rock blasted.

Mucking was done by using pneumatic showel loader and diesel locos for haulage. "U" shaped 25 cft. capacity trucks were used for mucking. As the width of the truck is 3′ at top, 2 trucks could easily be accommodated in the tunnel. The loader used were :—

Atlas Diesel 1/4 cu. yd.
Gardner Denver 1/4 cu. yd. (G.D.9)
Emico 21. 1/2 cu. yd. and
Joy showel leader 1/4 cu. yd.

The performance of Gardner Denver loader and Emico loader was very satisfactory. These loaders took 3 to 4 minutes for loading a truck, giving 15 trucks per hour. The mucking time per round was 4 hours. 12 ft. slide rails were used at the heading for movement of loader upto the face changing the rails once in two blasts.

Ventilation : Two electrical exhaust fans installed at the entrance of the adit for extracting gases and foul air from the tunnel served the purpose of ventilation. These fans were run by electrical motors, (Keith and Blackman) of 10 and 12.5 BHP,3 phase 440 volts, 950 RPM and 2900 RPM respectively. The pumping capacity of the unit was 5,000 cft./min. Two 20″ dia. 10-14 gauge M. S. sheet pipes, one for each of the faces were provided as ventilation shafts. They were installed and fixed to sides of the tunnel and supported at 5′ intervals. These pipes were manufactured in lengths of 8′ and 10′ by seam welding and the flanges were provided with 1″×1″×1/4″ M. S. angle. Two pipes were joined by the flanges with rubber packing inserted in between. The whole system was satisfactorily gas-tight. Similar arrangements were made at surge shaft end. A booster pump was installed at 1,000 ft. from adit to end ventilation for the maximum length of 2,200 ft. The ventilation pipes were taken upto 300 ft. from face. Clearnace took one hour time.

Illumination of Tunnel : The department supplied electric power at 400 volts at adit and surge shaft top, through 250 k.V.A. transformers of rating 22 k.V./440. Distribution inside the tunnel and service connections for works were arranged by the company. Three phase line and neutral were run for tunnel lighting. The mixer and welding set were provided with 30 amps, D.P. switches at Adit junction. To avoid voltage drop even for lighting, 3 phase line was run using varying sizes of wires. The maximum distance covered by the lighting system was 2,200′ in face 3.

Power Tunnel

Dewatering : Dewatering was not a serious problem though seepage existed at valley crossing which was not heavy. In faces 1 and 2 natural drainage through adit served the purpose, as the slope of the tunnel was towards the adit. In face 3, a deep sump pit was made at Ch. 1958 and at Ch. 2276 and the water collected was pumped through sump pumps connected to a 4" main, draining to the adit. In face 4 there was no seepage water.

Survey work : Survey work assumes a very important item in any tunnel and equally so in this tunnel. Before commencing the first adit, the alignment which was fixed originally during investigation was checked both by triangulation and by actual measurements. The survey of adit no. 2 was difficult owing to steep terrain. Selection of a proper base line with broad angles was the main hindrance.

During boring after every blast alignment was roughly marked by candles, extending suspended plumb lines in the already bored section, and the tunnel axis marked correctly. The alignment pins were driven in the roof at 50′ intervals. Theodolite stations were marked on the floor by fixing M.S. Plates at every 300 ft. and punching. Levels were carried from established bench marks and at every 500 ft. Inside the tunnel reference bench marks were fixed in the side walls of tunnel. The maximum error in alignment when 2 faces met was found to be 7/16″ with no error in elevation.

Table 1 : *Time cycle for boring a round of tunnel, 5′-0″.*

1. Survey : Marking centre line levels and position of drilled holes.	30 Minutes.
2. Drilling.	3 Hours.
3. Charging and blasting.	1 Hours and 30 Minutes
4. Clearnace of gas etc.	1 Hour.
5. Mucking.	4 Hours.
6. Changing track line and other preparation work.	1 Hour and 30 minutes.
Total	11½ hours.

Table No. 2 maximum progress on one face during a month.

Total advance for a month.	367′-3″
Rounds drilled and blasted.	66
Advance per round.	5½ ft.
Average daily advance.	11.8
Number of drills.	5 per round
Number of holes per round.	62
Total footage drilled during month.	23,372 ıft.
Average footage drilled per round.	354
Muck removed during the month per cu. yard.	2,252
Average explosive per cu. yard	3.30 lbs.

Months	*Face* 1.	*Face* 2.	*Face.* 3.	*Face.* 4.	*Total.*
7/55	21′	43′	40′-0″	....	104′-6″
8/55	126′	104′-6″	94′-6″	....	325′
9/55	174′-6″	189′-0″	134′-0″	....	497′-6″
10/55	67′-6″	210′-0″	169′-0″	....	446′-6″
11/55	Faces met on 13-11-55.	159′-6″	237′-0″	....	396′-6″
12/55	....	....	367′-3″	....	367′-3″
1/56	....	....	320′-6″	46′-6″	367′-0″
2/56	....	....	326′-3″	236′-0″	562′-3″
3/56	....	....	314′-3″	244′-0″	558′-3″
4/55	....	....	200′-6″	197′-9″	398′-3″
	389′	706′-6″	2203′-3″	724′-3″	4023′-0″

Lining of the Tunnel

The entire tunnel length was lined with concrete using reinforcement in special reaches vide fig. No. 1 The following was specified for lining:

1. Proportion of concrete 1:2 : 4 with graded metal. 70% $1\frac{1}{4}$″ and 30% $\frac{3}{4}$; river sand 90%, crusher sand 10%.

Form work :—Steel shutter in removable frames of 4′×2′ stable for pneumatic placer operation and power vibration.

Mode of Operation: Levelling course of concrete to be laid first below finished line; sides and invert to be hand placed ; roof portion to be lined with pneumatic placer ; sides and arch to be laid in continuous operations ; invert to be laid finally.

Mode of Supply of concrete: Mixers to be placed outside at adit and at surge shaft and conveyed or chuted, tip trucks being used for transport of mixed concrete.

Reinforcement

$1\frac{1}{2}$″ diameter rods double rows at $6\frac{1}{2}$″ c to c with 3/8″ distribution at 8″ c/c.

Lining was started in 3 faces viz., from forebay end towards adit 1, from Ch. 2318 towards surge shaft and adit finally closed at adit, the last 6 ft. bit being worked from inside and from the adit.

The steel shutters comprised of 5″ x $2\frac{1}{2}$″ channel rib with 4″ × 2″ channel uprights framed in two pieces and jointed by bolts at crown, with steel plates of 3/16″ M.S. plates stiffened at borders with $1\frac{1}{2}$ angles and flats in sizes of 4′×2″. The structure was quite robust and easy to handle in the absence of telescopic type shutter. The lining operation was taken in normal lengths of 20′ to 28′.

The work was started with the above steel form work. As placers (supply from Sweden) were received a bit late, lining work could be started only in third week of July 1956.

Mixing concrete outside as preplanned had to be abandoned since the same would become very stiff and consolidated in the trucks after conveying more than 1000 ft. due to jolting of the truck. Hence it was decided to keep the mixer inside suitably mounted to feed the placer direct. Hand placing concrete did not give rise to any problem but placer technique, being new, presented initial teething troubles.

Placer Concreting

Placer operation requires sufficient quantity of air as well as pressure. Hence 1000 cfm. of air supply at 80 to 90 lbs. pressure per sq. inch. was arranged at each face. A receiver of 56 cft. capacity was used coupled to the placer.

For inspecting the filling of the roof and sides above the springing level during placer operation, port holes were not provided in the shutter. Shutter plates were initially kept open. The fabrication of shutter plates did not permit easy insertion when the portion got filled. Subsequently slots of size 1′ × 1′ were cut in some of the panels for inspection and punning.

There was enormous wear on the delivery bend due to shooting of concrete. This was solved by insertion of a replaceable lid over top of bend made of special steel and this was coated with weld once in every third operation.

As the roof gets filled, the delivery pipe had to be withdrawn and air receiver connections being rigid lot of time was wasted in the movement. A dunlop rubber hose of 4″ diameter was used for air connection and this could not withstand 100 lbs. pressure. Hence these connections were made with victualic pipe joints in lengths of 2′ to 8′ to drag 6′ at a time for effective filling.

Liberal water content for concrete was needed to avoid blockade of delivery pipes and easy flow to the sides.

The delivery pipe was 6″ dia. as the tunnel lining was 8″ minimum in normal section and 14″ in R. C. C. reaches.

Unfilled Pockets

Careful supervision during roof filling was needed to avoid unfilled pockets in the roof. Trained men were needed for this job for satisfactory results. Generally placer concrete is not homogenous and will have to be grouted. Due to conjestion of reinforcement the lining of R. C. C. reaches presented many problems. Hand placing was resorted to a greater height in the case of R. C. C. resulting in poor progress.

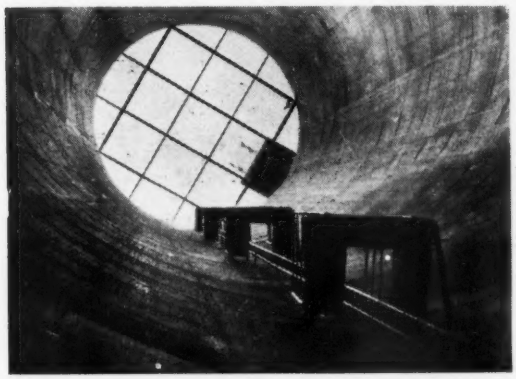
Seepage of water also presented difficulty for lining. Due to difficulty in conveying and placing of concrete, lap joint was avoided for the main reinforcement and welding was resorted after satisfying the results of sample lap joint.

As the quarries for metal and sand were far off the cost for procuring these items was very high. Due to the above and various other valid causes the actual cost of lining was observed to be on the high side and took more than specified period. The progress of lining was 16 ft. in R. C. C. and 56 ft. in normal sections per week.

As per modern practice the tunnel was grouted after lining for filling cavities. Grouting was also done for arresting seepage before lining. Grouting after lining gave satisfactory results. he entire tunnel was more or less free of seepage though sweating in the R. C. C. reaches could not be thoroughly arrested. The tunnel is grouted with 0.88 cft. of cement per foot run.

Surge shaft is a circular well of finished diameter of 40 ft. and height of 148 ft. sunk at exit of the power tunnel. This work involved 2,03,260 cft. of rock excavation and 39,105 cft. of concrete for lining.

Sinking of the shaft was taken up three months after commencing the power tunnel works with portable compressor for drilling, fuse coil blasting with light charges was adopted till a depth of 30′ was reached to avoid accident in the Kumili-Periyakulam road by shooting of rock pieces. The sinking of the shaft with heavy traffic on the road below, demanded very great vigilance and perfect organisation.



Surge Shaft

Mucking by head load was resorted to till the shaft reached a depth of 30′ by which time the hoisting arrangement and installation of electrical compressor was completed. The shaft was divided roughly into four sections for excavation purposes, for alternating the operations. Excavation was done in 5′ rounds. Same type of rock drills and drill rods were used for drilling and electrical blasting adopted using instantaneous detonators. Compressed air supply at this site was about 13,000 cft. per minute.

Broken rock was loaded by manual labour into 'V' shaped trucks and hauled up by an electric hoist (Wolf hoist crane) of 5 ton capacity with boom extending to centre of shaft. The muck was disposed into natural valley nearby. The sinking of the shaft after reaching R. L. 2722, i. e. 7 ft. above of the roof of adit 2 was regulated to avoid lapping with power tunnel work below and then bored through. Sinking took four months.

The shaft was lined with $1\frac{1}{2}$: 1 : 3 concrete, 1′-0″ thick with same proportion of agregates as power tunnel. Single row of 5/8″ rods at 9″ intervals of hoop reinforcement and verticals at 1′ intervals were provided. Steel shuttering comprised of 4″×2″ channel uprights with 4″×2″ channel circular ribs and curved shutter plates similar to power tunnel. The channel uprights were anchored to bottom stage of concrete and at top tied to rock for rigidity. This was typical of its kind for shaft lining. Separate timber scaffolding was erected in an annular ring braced suitably for men to approach and take the concrete platform. Concrete was mixed at top using two Nos. 7/5 cft. mixers and chuted down. The conreting was done in stages of 5 ft. (lifts) in complete rings with placing concrete by hand and consolidating by pneumatic vibrators. The average progress was 10 ft. per week.

The junction of pipe tunnel and surge shaft is of R. C. C. plug 20 ft. for embedding two square intake transition pieces for taking two 10′ diameter pipes. The concrete plug in between the two intake pieces is lined with 1/2″ M.S. plate fabricated to the shaft curvature. To ensure water tightness 1:$1\frac{1}{2}$:3 concrete with usual propertion of aggregates as power tunnel was adopted. The plug was formed in 24 operations continuously providing adequate keys in each stage.

High pressure grouting was done both in the surge shaft and in the intake plug. Very little grout was consumed either in the surge shaft lining or concrete plug.

Survey

Before commencing the work permanent reference points were established at ground level such that two points were diametrically opposite the shaft and with the channel point in the alignment of pipe tunnel. The distances and levels of these paints so located with reference to the centre of the shaft was correctly recorded.

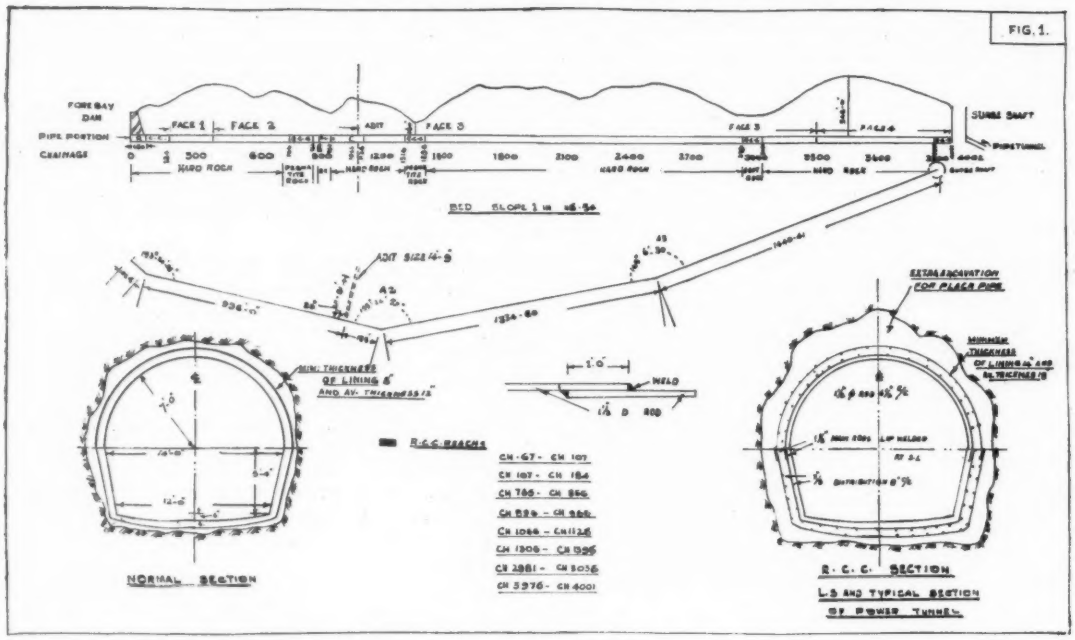
To start with a circle of 21 ft. radius was marked and excavation commenced. As the shaft was deepened, the centre was fixed by drilling vertically 10 ft. in the rock and fixing a rod. As the deepening was continued the centre was also deepened. The position of the centre was accurately checked with the help of reference points at the top and at every 10 ft. depth of the shaft. A weighty plumb was used for transferring the points. When the shaft sinking was completed the alignment of power tunnel was transferred inside the shaft by the usual suspended plumb line methods adopted for shaft survey using "Piano" wire and a weight of 30 lbs. (22 gauge).

Pipe Tunnel

To accomodate two 10′ diameter pipes a tunnel of size 30′-6″ of finished diameter, at 4′-6″ from floor of the tunnel is formed. The slope of the tunnel is 1 in 4.34 and the horizontal length from the face of the surge shaft is 180 ft.

In view of the steep slope and large section, the driving could not be done in full face. A pilot tunnel was bored from either ends. After this was through, the tunnel was trimmed at the top to the required section and the bottom benched. The same equipment of the power tunnel were used for drilling. Ordinary blasting was adopted. Muck was manually loaded into tip trucks (1 cyd. trucks) and disposed into natural valley.

The entire length of tunnel was lined with 1:2:4 concrete using rail rib reinforcement. The concreting operation was done by manual labour using machine mixing inside the tunnel. To facilitate the lining operation the sides upto 5′-2″ height were lined in advance, and the arch portion was tackled subsequently taking 8 ft. at a time. The arch portion took 24 hours and sometime more for completion. The work in the pipe tunnel was completed in advance to facilitate erection of penstock pipes.



Conclusion

The construction of power tunnel, surge shaft and pipe tunnel took 2 years and 9 months against the stipulated period of 2 years as per terms of contract. This delay was mostly due to the diversion of equipment and labour etc., for the irrigation tunnel works during the closure seasons of three months each in 56 and 57. There were no special problems during execution of work hindering the progress. Trained men and machanics were employed on the job. Equipment being more or less new, the maintenance of machines was less costly. Generally there was no failure of machines due to want of experiened personnel and spares.

The cost of power tunnel worked to :—

(*a*) Excavation: Re. 1-7-0 per Cft.

(*b*) Lining Rs. 328/- per Rft.

The finished tunnel costs Rs. 675/- per Rft. per including excavation, lining and grouting.

The labour engaged by the tunnel contractors were insured. There were only three fatal accidents and many minor accidents. The details of the power and pipe tunnels and surge shift are given in the following statement :—

Item	*Power Tunnel*	*Pipe Tunnel*	*Surge Shaft*
1. Area upto neatline of excavation.	182 Sft.	641.73 Sft.	1385.44 Sft.
2. Pay line of excavation.	199.13 Sft.	676.10 Sft.	1429.85 Sft.
3. Final area of excavation.	217 (Av) Sft.	684 "	1483.44 Sft.
4. Overbreak	35 Sft.	42.27 Sft.	98.00 Sft.
5. Percentage of overbreak over neatline of excavation.	19.2%	6.58%	7.08%
6. Minimum thickness of lining.	8"	16" sides and top 12" bottom.	1'-0"
7. Average thickness of lining for payment	12"	22" at top and 16" bottom.	1'-4"
8. Final thickness of lining (Average)	16"	23" top 17" bottom	1'-8"

Improvements to the Existing Irrigation Tunnel

The details of the tunnel are as follows :—

Length:		5892′
Bore:		12′ × 8′
Total bed fall:		78.75
Average gradient:		1/74.7
Discharge capacity:		1400 cusecs.
Existing Shaft:	1.	17′× 17′ × 60′
	2	12′ × 6′ × 120′

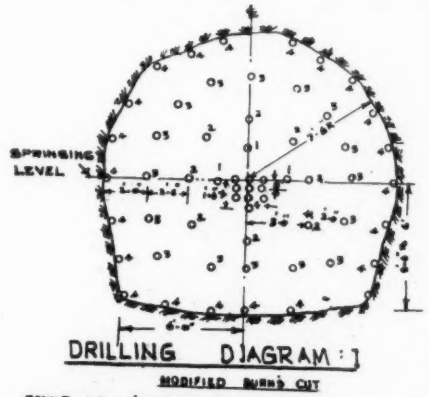
Improvements to the existing irrigation tunnel which has to discharge the maximum power draft of 1600 cusecs, consists in enlarging the sectional area of about 120 Sq. ft. to 199.13 sq. ft. with a finished water way 151.67 Sq. ft. after lining with 6″ minimum concrete. The existing emergency and regulating hand-operated gates were decided to be replaced by a new electrically operated regulation gate at shaft I. The leading channel, nearly 7000 ft. long, was lowered by 5 feet with the still at the inlet of the tunnel. A new emergency gate equipped with electrical operation was provided at the inlet of the tunnel. The old trash rack bars were also replaced. The provision of emergency gate and lowering the leading channel were executed by the Public Works Department.

Improvement work: The work being seasonal during irrigation closure season of March to May, it was planned to carry out the work in three season . But actually work was extended to fourth season also. Enlargement was started departmentally in 1955 immediately after the inauguration and only 1000 ft. could be tackled owing to lack of equipment, etc. Before the next closure season in 1956, the work was entrusted to M/s Patel Engineering Company who were contractors to power tunnel, to complete the work in two seasons, 1956 and 1957. To push through the work an additional shaft of size 15′×12′ located at 2000ft. from exit was sunk as required by the contractors. This provided six workig faces. As the gates at head sluice were not watertight, effective sealing was done departmentally.

Sinking a new shaft 2000 ft. from exit, installation of head gear, compressor etc., were completed before March 1956, regular preparation being started a month in advance. As the time available in each season was only 12 weeks including arrangements to enter the tunnel and clear out before the opening date, the works were carried round the clock, in all the faces.

The tunnel line was accurately surveyed and final alignment fixed such that existing several kinds are eliminated. The survey work was carried out depeartmentally and the alignment furnished to the contractors. Sides and bed were trimmed by using five feet rods and the roof with fifteen feet rods. Dry drilling was adopted for convenience. Very often roof holes were drilled by standing on muck heap though in a few places a pipe platform was used. Generally trimming was done in 10 to 15 feet rounds. 75% gelignite with electric detonators were used. Two blasts were done daily in each face at specified hours with proper co-ordination from each face. The existing regulation gate was adequately protected from damage, due to blasting. The explosive ratio for enlargement worked out 5.94 lbs. per 100 cft. of rock.

FIG. 2



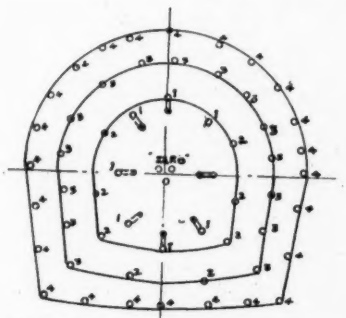
DRILLING DIAGRAM : I

MODIFIED BURN'S CUT

ROUND OF 8′ WITH A PULL OF 85%

DELAY	TYPE	NO OF HOLES	DEPTH OF HOLE	CHARGE PER HOLE	TOTAL PER SET
0	CUT HOLES	4	9′-6″	3½ LBS	14 LBS
1	-	4	9′-0″	3 "	12 "
2	EASERS	5	8′-6″	2½ "	20 "
3	-	14	"	2¼ "	36 "
4	TRIMMERS	23	"	2 "	46 "

NOTE 1. 0 & NOS BLANK HOLES
2 LESSER CHARGE IS ALSO USED
EXPLOSIVE RATIO 2.8 TO 3.2 LBS PER CUBIC YARD



DELAY	NOS	LENGTH	FOOTAGE	CHARGE	TOTAL
0	3	5′-0″	15′-0″	2½ LBS	2½ LBS
1	5	7′-0″	35′-0″	2 LBS	10
2	8	5′-6″	44′-0″	-	16
3	14	5′-6″	82′-6″	-	28
4	24	5′-6″	132′-0″	-	48
				TOTAL	118½

PULL 5′-6″

DRILLING DIAGRAM · II

POWER TUNNEL

Removal of muck from a round, took several hours. The fracturing of rock by blasting was not quite satisfactory. Large pieces of rock had to be broken by hammermen as there was no time for secondary blasting. As the access to the tunnel was only through the shafts, mucking was done by manual labour upto the shafts from where they were hauled by hoists and disposed of. It was not feasible to take loaders and locos inside, as work was going on in six faces during blasting when they could not be protected adequately.

The average out-turn of mucking in each face was :

Face 1 :	96 trucks per day.
Face 2 :	45 trucks per day.
Face 3 :	60 trucks per day
Face 4 :	120 trucks per day.
Face 5 :	85 trucks per day.
Face 6 :	100 trucks per day.

As the hoist was used for haulage of men and materials also, the progress of mucking could not be accelerated.

Concrete Lining

After detailed inspection of the rock after enlargement, it was decided to provide lining for 1200 ft. each, at inlet and exit ends and weak zones in between covering about 700′.

The procedure of lining was to provide (*i*) a skin floor of 1:3:6 concrete as a levelling course throughout the tunnel ; (*ii*) Form sides upto axis level using timber shutter with 1:2:4 concrete using 70% 1½″ metal (1″ metal used in R.C.C.) and 30% 3/4″ metal ; (*iii*) place arch lining by pneumatic placer using steel shutter ; (*iv*) form the invert finally.

Broken rock was procured with a lead of three miles and river sand conveyed from 15 to 20 miles.

Only machine mixing was done, mixed at top and chuted through 6″ pipes down the shafts and conveyed to site by tip trucks. Sometimes, mixers were placed inside for lining by placer.

R.C.C. Lining : R.C.C. lining caused additional difficulties due to delay in placing reinforcement and placing concrete was also slow. R.C.C. was adopted in selected zones.

Inlet	228′
Weak zones	252′
Exit end	105′
Total	585′

The procedure followed for R.C.C. was to place the invert first with the reinforcement upto axis level, then the top reinforcement is placed lapping the bottom and then lined. Single row of 1″ rods at 6″ centre to centre as main reinforcement, with 1/2″ rods at 12″ centre to centre as distributors, formed the reinforcement. In some sections placer was used for placing both sides and roof to gain time unlike the power tunnel where sides were lined by hand-placing. The question of accommodating the placer pipe did not arise here as no definite overbreak was specified unlike the power tunnel.

Progress of work

Trimming : 300′ per month per face.
Length lined : 368′ per month per working face (lining was not done in all faces)

Total quantity of excavation in Tunnel enlargement :	7,80,000 Cft.
Concrete placed :	3,27,840 Cft.
Steel used :	71 tons.

No ventilation arrangements were needed in view of the three shafts.

Regulation gate at Shaft No. 1

Regulation of water is required for a head of 51 ft. and a dry well was specified for purposes of inspection. The gate was installed on the upstream end of the shaft. The gate is provided with operation by manual labour also.

The shaft was trimmed to provide the embeded parts of the gate and the entire shaft height upto 2855 level was lined and the headgear provided. The gate was supplied by Messrs. M.A.N., Germany.

1. Size of the gate	5247 mm. wide × 654 mm. thick × 4023 mm. high.
2. Weight :	14 Tons.
3. Sealing, special bulbed rubber for sides and top and plain for sill.	
4. Wire rope used (2)	30 mm. diameter
5. Speed for lowering by electric motor	3 ft. per minute.
6. Inspection platform at	2865 level.
7. Operation platform	2882 level.
8. Sill of gate	2810.35 level.

Special problem during work :

As the work was located in the Kerala State, special permission had to be obtained for constructing structures, dumping the muck etc. The movement of vehicles at night was restricted. As the enlargement had to be tackled with habitation close to the tunnel, slight damages to the walls in the form of cracks were observed, due to the heavy vibration caused particularly by electric detonators.

Preventing effectively the leakage water, past the old gate, earth had to be dumped in front of the emergency gate. Clearing of this enormous quantity of dumped earth, necessitated employment of divers and allied equipments, to open the emergency gate. This operation in 1956 involved postponement of supply of irrigation water by three days which had to be specially got sanctioned by the Government.

[*Continued on page* 37

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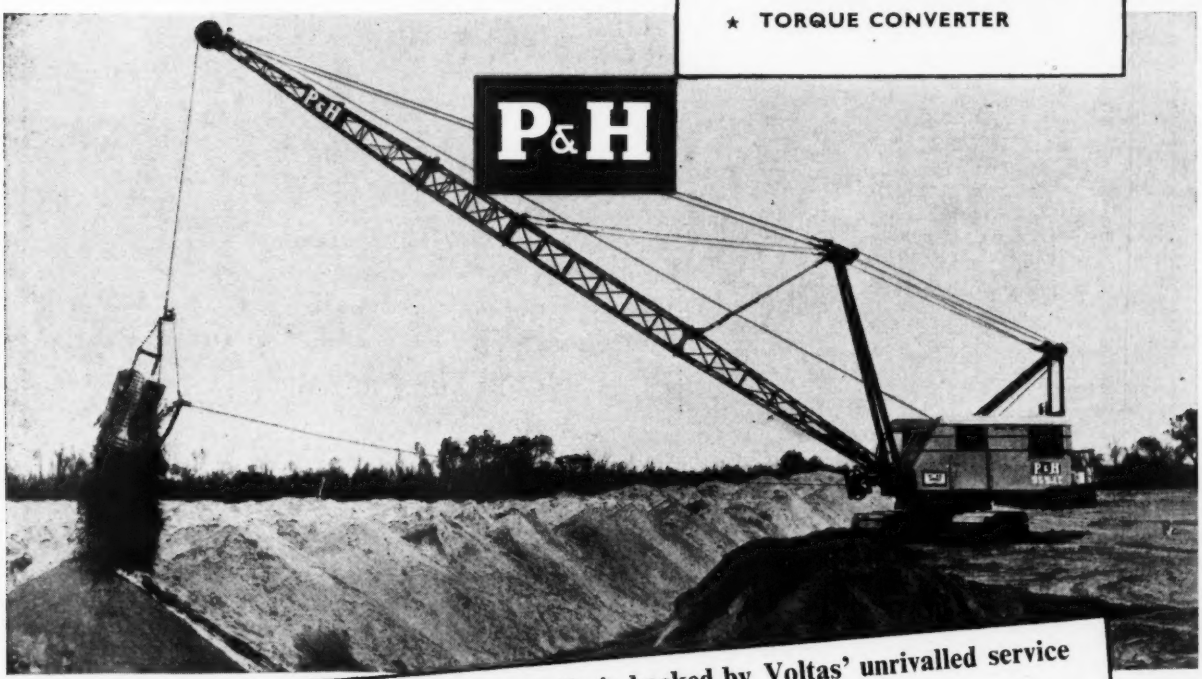

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Periyar Power House Generating Plant

By S. MOHAMAD ALI,

The Periyar Power House with a generating capacity of 1.23,600 kVA in the 1st stage under execution and an ultimate capacity of 164,800 kVA joins the Madras Grid consisting of four hydro-electric stations and two thermal stations with a total capacity of 2,86,000 kW. This station with three generating sets of 41,200 kVA each will be the biggest unit of the grid until the Kundah station makes its entry into the grid in a couple of years.

Water from Periyar Lake is led through two tunnels and 3350 feet of penstock with a gross head of 1269 feet to turn the 50,000 HP water wheels. With the adoption of a high speed of 750 R.P.M. for the reaction turbines at 1269 ft. head, there has been a considerable saving in the cost of the hydraulic and generating equipment.

Plant Contracts

Contracts for the various equipments were placed with different firms taking into consideration the cost of equipments, reputation of the manufacturing firms to guarantee proved performance and the delivery period for the early commissioning of the Power Station. The important contracting firms are :

M/s. G.M. Voith, West Germany	Hydraulic equipment
M/s. A.E.G., West Germany	Generating sets, indoor Switchgear and cooling water equipment
M/s. Oerlikon Engineering Co., Switzerland.	Step-up power transformers
M/s. ASEA, Sweden	Outdoor switchgear including 110 kV MOCBs
M/s. A.E.I. (India) Ltd.,	11 kV cables and 110 kV switches.
M/s. Jonhson & Philips, Philips, F & C Osler	Control and L.T. power cables.
Mavag Bridge and Crane Factory, Hungary.	100/20 Ton Travelling crane.

The whole equipment is of a very interesting character and will be described in greater detail, hereafter.

Transport of materials to site : Transport of materials was by rail from Madras to Theni RS. From Teni to Power House site, road transport of 35 miles limited the weight of a single package to 21 tons in the interest of safety to bridges.

The limitation of weight had an important bearing on the design of major parts of turbines, generators and of transformers.

Power House Layout

The machine hall is of the double floor type. The lower floor houses the turbines, governor, servomotors, oil pumping sets for governor and bearing and oil pressure receiver. In the top floor are placed the generators, turbine actuator, manometer panel, field suppression switch and CO_2 equipment for generator fires. At the western corner of this floor is the air compressor equipment for operation of the generator brakes and air-operated switches in the 11 kV cubicles.

The 11 kV switchgear and house supply unit transformers with their 400 V unit boards are housed in a separate floor in level with the repair bay and running parallel to the machine hall on the south side. At the eastern end of this floor is the valve house for the pressure-water fire fighting equipment of power transformers.

A spacious power and control cable duct runs beneath the switchgear floor. Above this switchgear floor is situated the control gallery, housing the control panels, relay and regulator equipments, 400 V.AC and 220 V. DC boards and the station battery.

The outdoor 110 kV yard has ben located east of the Power House building. The power transformers, 110 kV structures with circuit breakers and 110 kV PTs and CTs form part of this outdoor yard.

The cooling water pumphouse with three pumps is

located in the annexe built as extension of the Power House building at the north-east corner. The water is pumped from the tail race pool.

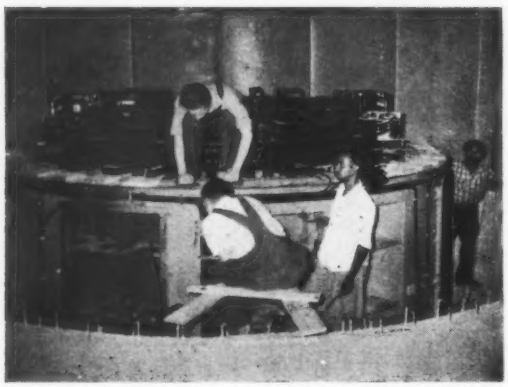
The machine hall is served by a travelling crane designed to handle a maximum working load of 100 tons and with an auxiliary hoist of 20 tons. This crane after departmental erection was tested upto 25% overload.

Hydraulic equipment

The station is equipped in the first stage, with three vertical shaft reaction turbines, directly coupled to their generators. The units are designed for a maximum continuous load of 50,000 HP under a nett load of 1225 feet with a discharge of 400 cusecs at maximum load. The speed of the set is 750 RPM with the specific speed at 21.1 RPM.

A liner of welded fabricated steel plates is fitted to the top portion of the concrete draft tube. The portion adjacent to the runner is made of stainless steel. The liner is completely enclosed in reinforced cement concrete except for the manhole portion. A travelling gantry at the tail race side handles the locally manufactured gates for the draft tube and pressure relief outlet.

The spiral casing is fabricated from welded mild



Generator being assembled

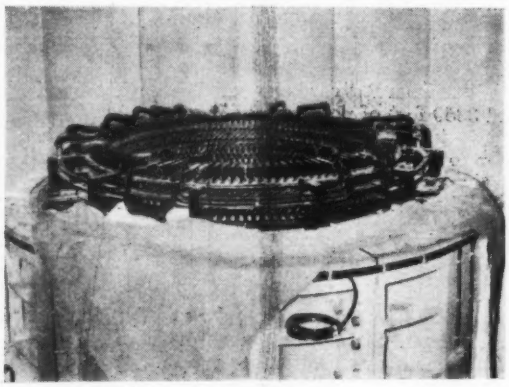
steel plates graduated in thickness 5/8″ to 1″. The welding seams have been X-rayed and the whole spiral casing has been stress relieved by annealing after welding and tested at works. The casing has an inlet diameter of 45″ and is substantially circular in cross section.

The spiral casing plates are butt-welded to a central cast steel speed ring with ten stay vanes of which one is designed as a baffle vane.

For convenience of transport, the casing and speed ring were split into two parts. At site, they were bolted on the inside and rivetted on the outside with two straps overlapping the jointing ends.

The spiral casing is connected to the penstock pipe by the inlet rotary valve and two lengths of pipes 20′ long each, jointed by rivetting. The pipes and the casing are completely encased in reinforced concrete. Because of the shape of the casing and the reinforcements-rods around it, placing of concrete underneath without voids presented difficulties. 1″ pipes were placed at intervals around the casing and after concreting, pressure grouting was done to fill in any voids.

The runner, which is always submerged in water is of integral cast stainless steel with 13% chromium. Because of the high head the passages through the runner are very small (about 2.25″ at the outlet). It may be of interest to note here that for a gross head of 1269 ft. reaction turbines have been installed for the first time in India. It has two outer bearing rings, and two labyrinth rings of special chrome steel. The runner is attached to the shaft by bolts well secured. The labyrinth rings will not only relieve to some extent the hydraulic thrust on the thrust bearings but will also ensure stability of the turbine runner against vibration. The runner can be removed for any attention after dismantling an intermediate shaft between the turbine and generator shafts and the head cover.

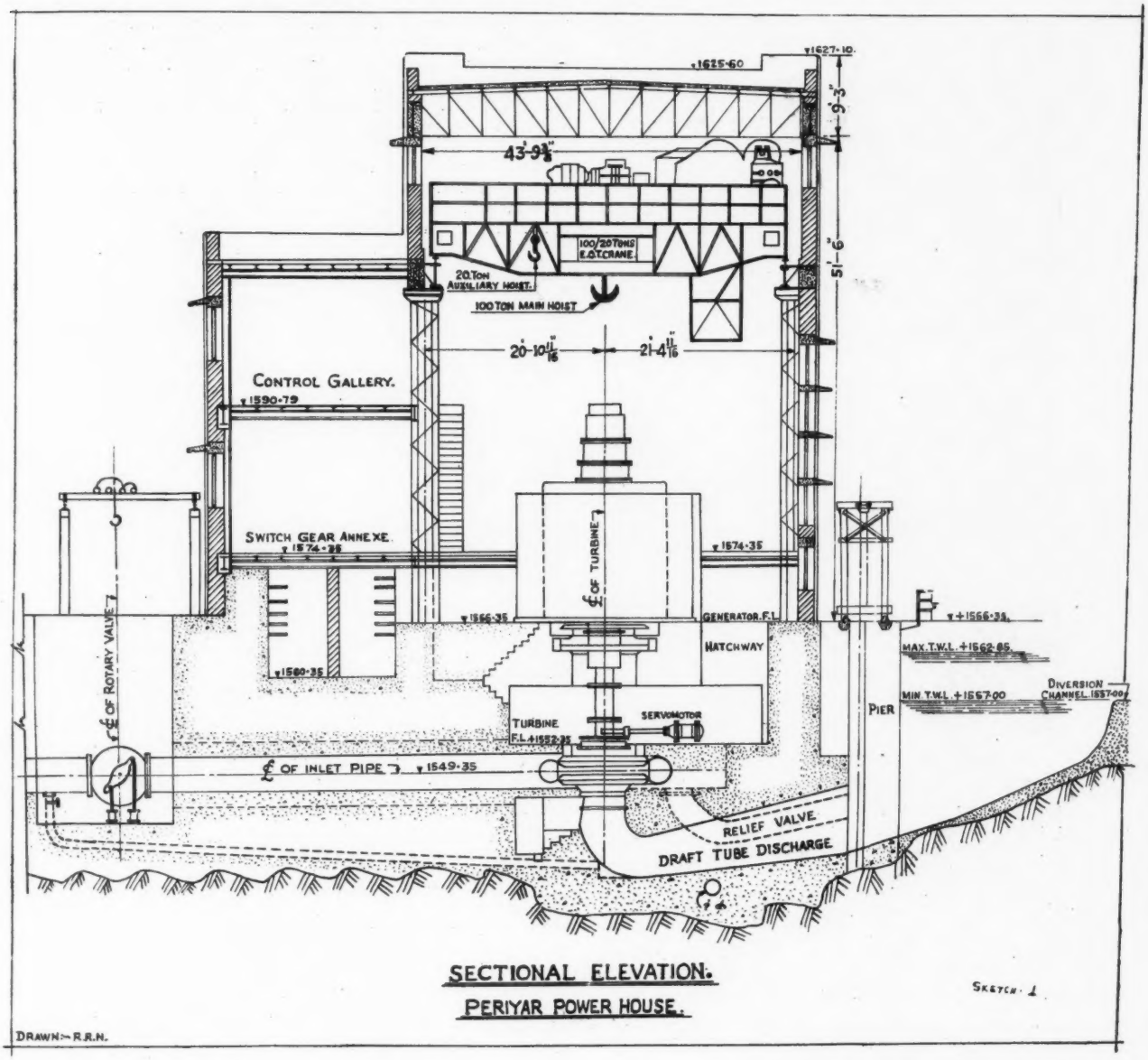


Generator after assembly

The regulating machanism for the control of water to the runner consists of twenty wicket gates made of stainless steel in one piece. The stems are not provided with additional sleeves. If after years of service the sliding surface of stems is slightly worn out a portion of the stem will be turned off and stainless steel sleeve inserted. The wicket gates are operated by a regulating ring of cast steel to which they are connected by guide vane levers, split, of cast steel with breaking bolts. These bolts are so dimensioned that they will break in the event of an obstruction such as wood or other debris and release the particular gate from the regulating ring.

The regulating ring is supported on the turbine head cover and slides on well—lubricated bronze pads. It is operated by two pull rods attached to the Governor servomotors.

The turbine head cover is of fabricated cast steel construction and is rigidly bolted to the speed ring.

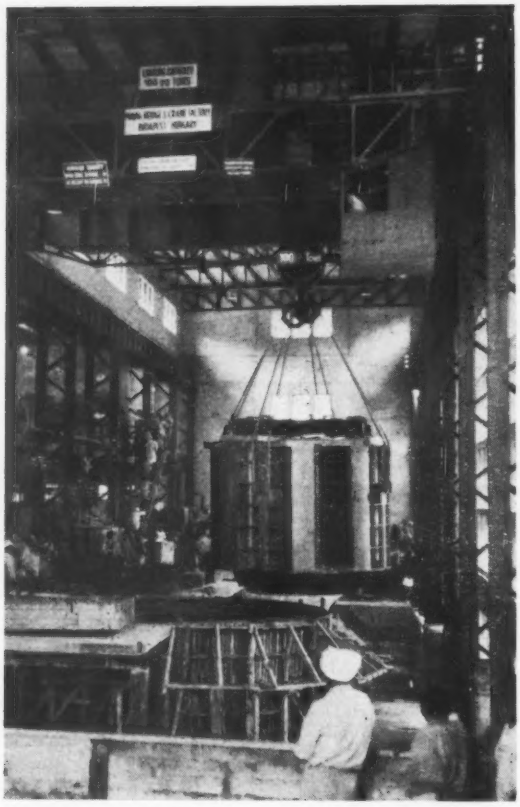


It carries the turbine guide bearing housing. It also carries seating for the turbine shaft water seal of sectionalised carbon rings. The bronze bushes for the top stems of the wicket gates are housed in this cover. Stainless steel liners are provided on the head cover and the bottom guide wall in order to reduce water leakage, whereas the rings on the runners are made of normal steel.

The guide bearing bush is lined with white metal with suitable grooves for oil lubrication. The lubricating oil is fed by an A.C. motor pump through a cooler. A DC motor pump serves as automatic standby in case AC supply fails. The bearing is complete with the normal accessories including oil return, oil level indicator, temperature indicator and a safety valve on the oil circuit.

Oil Pressure Governing System

As stated earlier, the turbine gates are operated by a regulating ring which in turn is operated bytwo control rods connected to two oil servomotors of the governing system. The speed governors are of the cabinet type with a capacity of 40,000 ft, lbs. The actuator pendulum is driven by a synchronous motor run from a synchronous generator mounted on the top-most end of the generator shaft.



Generator stator being moved to position

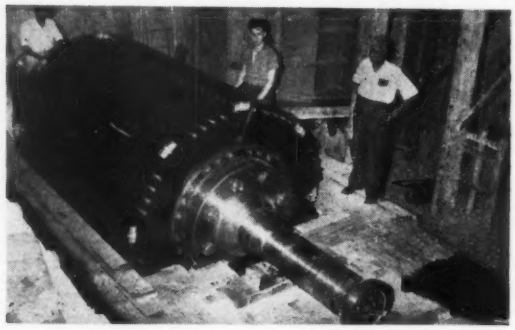
The servomotor receives its oil supply from an oil pumping system which consists of an oil pump, oil pumps for electrical drive, pressure tank, safety valves, and oil cooler and other accessories. A DC motor pump with pressure release arrangements serves as automatic standby to the normal running AC set. The pump set maintains the pressure in the tank at 20 atm. with unloader valve set to work between 18 and 20 atm. The governor is fitted with a special quick closing device which will shut down the turbine in following circumstances:

(*a*) Governor oil pressure dropping down to about 14 atm.
(*b*) Bearing temperature rise to about 70°C.
(*c*) Turbine reaching an overspeed of about 33%.
(*d*) Electrical faults on generator and switchgear.

The governor closing time, on suddenly throwing off the full load, has been set not to be lower than 3.2 sec. The Governor closing time is such that on suddenly throwing off 100% load the maximum pressure rise does not exceed 30% of the gross static head and the speed rise does not exceed 30% of the normal speed provided the flywheel effect in generator is not less than 0.5×10^6 lbs/sq. ft. It has been guaranteed that sudden loadings on the turbine by 60% full load and subsequent further loading by 40% full load will cause only a speed drop of 30%.

Hand gear machanism and restoring mechanism (cr return motion gear) are incorporated in the governor system. Temporary speed variation can be effected by remote controlled reversible electric motor. The permanent speed variation is capable of being adjusted.

Air inlet pipes with predetermined valve settings are provided in the draft tube liner below the runner, the function of which is to admit air to the draft tube when the turbine gates are being closed in order to restrict excessive vacuum or shock due to the sudden rupture of water column.



Generator Rotor after assembly

An air inlet arrangement is also provided through the hollow turbine shaft to introduce air into the space just below the runner under certain operating conditions to avoid vibration.

The set is designed to stand a runaway speed of 1375 RPM (or 83% above normal speed). To prevent the runaway speed, an overspeed device set to operate at a predetermined figure shuts down the turbine and closes the inlet valve.

Inlet Valve

The water from the penstock to the turbine is controlled by a rotary valve of robust construction. Two external servomotors actuated by pressure water which is controlled by a pressure oil operated control valve are erected to carry out the opening and closing operations of the valve. As soon as the pressure on the spiral casing and penstock is equalised when the bypass valve is opened, a pressure switch initiates the opening of the valve.

The hemispherical door of the valve closes the pipe bore by sealing against a gun-metal liner inside the main casing when forced by pipe line water pressure. In the open position the opening in the rotary valve body forms a continuation of the pipe line bore so that smooth flow conditions are ensured. The opening and closing times are about 60 seconds and can be altered. A travelling gantry with a crane capacity of 20 tons is erected for erection and removal of the rotary valve. During the erection of valves 1 and 2, the crane was not ready and hence the valves weighing about 15 tons each, were moved to their position through the inlet pipe blockouts from the machine hall

side by improvised means. The third valve has been lowered from the upstream side by chainlocks.

Relief Valve

Hydraulically operated relief valves (pressure oil for closing and pressure water for opening) are fitted to the spiral casing to limit the maximum pressure rise in the pipe-line to 15% of the maximum gross head while throwing off full load. Without this relief valve, the pressure rise in the pipe line is expected to go up to 30%. The valve has been designed to by-pass the full load discharge of 400 cusecs.

Synchronous Condenser Operation

Generator No. 3 was later on decided to be used as a synchronous condenser when water conditions during a particular season and period, do not permit generation in the station. As the normal water level in tail race is above turbine runner, the suppliers proposed lowering of the draft tube water level by compressed air during this operation which involves additional equipment. At the suggestion of the department, it was decided to lower the draft tube water level by lowering its gate and pumping out the water. This improvement has saved the department a considerable amount of expenditure. For synchronous condenser operation, provision is made to supply cooling water for the upper and lower clearances to avoid dangerous rise of temperature.

Drainage equipment

For draining the leakage water and emptying the spiral casing, inlet pipe, draft tube, and pressure relief pipes, a drainage channel is run under the northern side of the machine hall. Two motor pumps of capacities 880 galn. per min. and 2,800 galn. per min. respectively are installed in the bottom machine floor for automatic operation with float control to pump out the water to the tail race.

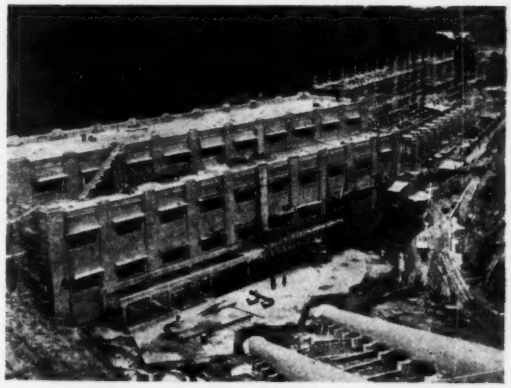
Alternators

The vertical direct coupled alternators are each rated at 41,200 kVA 0.85 p.f. 750 RPM rated voltage 11000V +1000V
−2000V

The stator, which was supplied in four parts without windings, was completely assembled at site and erected on the machine house floor. The core is built up of 0.5 gauge high alloy non-aging silicon steel sheets of high permeability and low loss figure, coated on one side with mica base varnish. The winding is of the two-layer Roebel bar wave type with insulating varnish of bitumen bass-class B.

The continuous ring supporting the end turns is of non-magnetic steel. In order to reduce the heating effect due to eddy currents, the distance between the ring and end turns is increased, wooden segments being inserted between them. The end bells of the generator are made of Duraluminium in order to reduce the heating effect due to the stray flux.

As generally required in water turbine generators, the rotor is designed to be heavy to give a high flywheel effect, in this case 1.05×10^6 lbs. sq. ft.. The



Power House and Transformer yard

rotor is of lapped construction, the yoke ring being built up of twenty-two 150 mm. thick. rolled steel plates with recesses for taking up the pole cores. At the two ends of the rotor, plates of non-magnetic steel are welded. The pole shoes are laminated and bolted to the rotor body. The winding is made of edge-wound bar copper strip coils with some of the strips projecting to increase the cooling surface.

A liberally dimensioned damper winding has been provided to ensure satisfactory parallel operation of the generators and to provide sufficient protection under unbalanced loading and on single-phase short circuits. The complete rotor weighs about 82 tons.

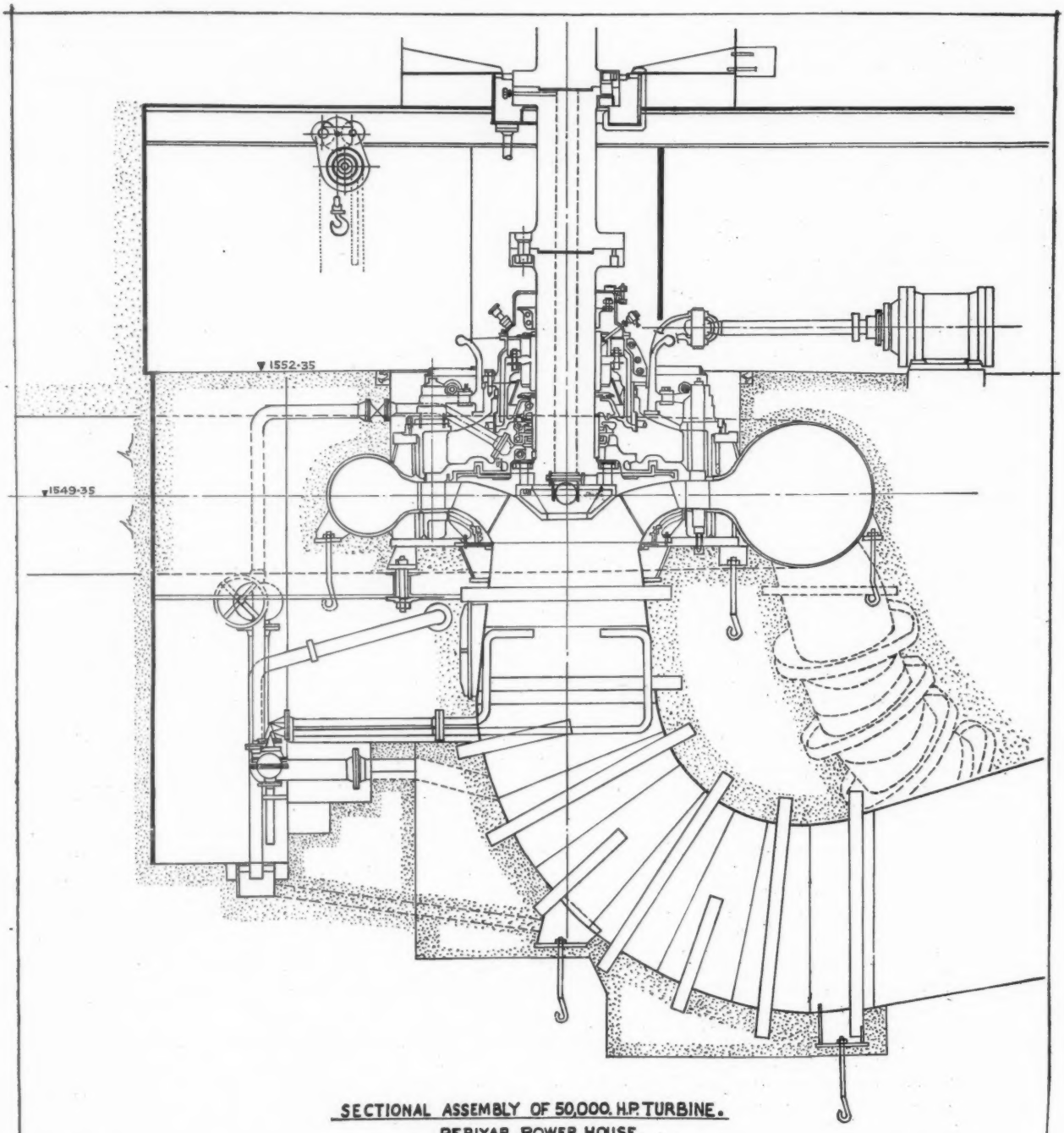
Shaft

The shaft is forged of high quality steel and its two parts are bolted to the rotor at either end. The generator shaft diameter is 370 mm. as against the turbine shaft diameter of 450 mm. It is claimed that the smaller diameter of generator shaft has resulted in reduction of losses caused by friction and in lessening the vibrations.

The alternator is of the two bracket type in which the thrust bearing for carrying the rotor rests over the stator frame and there is a guide bearing on each side of the rotor. The upper guide bearing combines with the thrust bearing in the upper bracket.

The Mitchell type thrust bearing has been designed to safely take the load of the rotor and the runner in addition to the hydraulic thrust from the turbine runner. The bearing is of the self-pumping type with the rotating collar, which is provided with bores acting as a pump impeller of a centrifugal pump. The thrust collar is surrounded by a spiral pressure chamber of increasing diameter from which the oil is conveyed to the cooler arranged at the stator circumference. The pressure in the chamber is about 2 atm. at 750 RPM. Two cooler units are provided, one of which is a standby. The cool oil flows back to the oil pump of the bearing and is forced by an annular distributing pipe through nozzles into the clearances between the thrust pads and the centre of the bearing.

The two guide bearings, also of the self lubricating



SECTIONAL ASSEMBLY OF 50,000 H.P. TURBINE.
PERIYAR POWER HOUSE.

DRAWN:—R.R.N.

type, consist of segments lined with babbitt metal and the segments can be adjusted in radial direction. The bottom guide bearing which is mounted on a spider bracket is independent of the upper bearing and has its own oil receiver and oil cooler. Spirally rising grooves in the collars enable the oil to be properly supplied and the oil returns to the oil receiver through holes provided in the bearing bush. Mechanical seals and special pressure chambers seal the bearings against oil leakage.

The generator can be run for 15 minutes without cooling water to the bearing oil without abnormal rise in temperature.

Bearing currents are prevented by providing insulation for both thrust bearing and lower guide bearing.

Each arm of the lower bracket carries a braking and jacking cylinder supplied with compressed air at 20 atm. for braking and oil at 246 atm. for jacking.

The braking arrangement is suitable to bring the rotating parts from 300 RPM to rest in 6 minutes. With the jacking arrangement, the rotor can be lifted up by 25 mm. for inspection or replacement of the thrust pads. The compressed air equipment consists of an A.C. motor driven compressor and the oil for jacking is supplied by a portable hand operated pump.

Generator cooling system

The generator has been provided with a closed circuit cooling system with four cooler units uniformly arranged on the stator periphery. The cooling air is forced by the suction effect of the poles through pole gaps, the air duct arranged radically between the stator laminations and through the end turns. The hot air emerging from the stator is passed through the water cooled heat exchangers and then to the axial flow fans fitted on top and bottom of the rotor.

The air cooler is capable of being attended to for service without shutting down the generator. With one cooler unit cut, the generator can be run at rated load without abnormal rise in temperature.

Cooling Water

The cooling water for the air and oil cooler units of generators, turbines and transformers is supplied from the tail race pond by installing 3 A.C. motor driven centrifugal pumps (each 117 HP 1650 GPM). Each pumpset is designed to feed the water requirements of two generating units.

A standby water tank with a capacity of 44,800 gallons is connected to the water system to feed water for about 15 minutes in emergencies caused by supply failure to cooling water pumpsets.

A complete set of CO_2 fire quenching equipment is provided for each of the three generators and is operated automatically by electrical relays controlled by thermostats installed around the stator.

Excitation System

The main and pilot exciters are directly coupled to the upper end of the main shaft. The exciters are of the open type, self-ventilating and drip proof with windings of class "B" insulation. The pilot exciters of 3.5 kW capacity is self excited and supplies the field of the main exciters of 130 kW continous capacity at a constant voltage of 115V., the current to the field being controlled by an automatic B.B.C. voltage regulator. The ceiling voltage and current are 240 V (normal full load voltage being 120 V) and 2160 Amps with the response ratio in Volt/Sec. = 1.5.

The following guaranteed particulars with respect to the generating set will be of interest.

1. Runaway speed 1375 RPM
   Lowest critical speed 1672 RPM

   At the runaway speed the set is capable of operating for 5 mts. without mechanical damage to any part.
2. M. C. R. at 0.85 p. f. lag. 35000 kW
   1.00 41200 kW
3. Maximum temperature rise in continuous operation at 11 kV with full load:—

   Stator winding 50°C. (resistance elements)
   Rotor winding 50°C. (resistance)
   Iron core and other component parts: 50°C.
4. No load short circuit ratio: Not below 1.5
5. Efficiency at 41200 kW unity; p.f. 98.3%
   35, 500 kW—0.85 p.f. 97.8%
6. Condenser capacity 28800 kVA at 0.0 p.f. overexcited and 100%full load excitation.
7. Line charging capacity at 0.0 p.f. underexcited at 9 kV and 15% full load excitation—39,200 kVA.

Transformers

The generated voltage of 11 kV is stepped upto 110 kV for transmission. The power transformers for this purpose are single phase units rated at 14 MVA to provide a bank of 42 MVA for each generating unit. The lower voltage side is delta connected on special structures and the high voltage side is star connected with the neutral point earthed through a C. T. to afford protection by a restricted earth fault relay. The H. T. windings have 3, 6, 9% tapping connected to an externally operated off-load tapping switch. The transformer oil is cooled by circulating it through a water cooled cooler.

The H. T. windings of sectionalised disc construction are paper insulated and oil impregnated with graded insulation. The LT windings which are fully insulated, are of transposed multi-conductor spiral construction.

The outgoing cooling water from the cooler is taken through an open discharge tank to observe any traces of oil leak in the cooler. The top of the water chamber of the cooler is provided with a pipe to serve as a safety release if the water pressure exceeds a predetermined value.

The silica-gel breather is of the multi-passage type to increase the path of air through the gel. A double action valve is attached to the air entry on the bottom of the air dryer to admit air only when an excess of suction preassre of about 0.2 atm. occurs.

One fully equipped transformer is kept as unconnected spare to the nine single phase units. The transformers were shipped without oil and outer fittings and filled with nitrogen gas. Total weight of each transformer fully erected and filled with oil is about 27 tons.

As protection against fire, the transformers are covered by Walther & CIE waterspray protection system. Partition walls are provided between trasformers to restrict the spread of fire.

Indoor switchgear and control panels

The key diagram of Periyar station is shown in Fig. 3 and it will be seen that the unit arrangement has been adopted. The transformers are solidly connected to the generators. The generator terminals are connected to a 11 kV bus in a cubicle opposite each set by means of bar copper enclosed in a special duct. Four cables for phase of 500 Sq. m/m (0.775 sq. inch) connect the transformers to this bus. This cubicle houses the surge arresters and capacitors, 11 kV/110 kV potential transformers for metering and voltage regulator and the neutral is earthed through the neutral transformer (50 kVA 8 kV/110V) by a 10 sq. mm cable.

From one end of this 11 kV cubicle, a tapping through an enclosed short circuit proof bus duct is taken to the station (unit transformer of 500 kVA/11 kV/400V). The three station transformers are clophen filled (instead of the normal oil filling) as a safety against oil fire risks inside power house and hermetically sealed to prevent evaporation of the liquid. The isolating switches controlling these transformers are operated by compressed air mechanism, pressure air being fed from the compressor unit installed for braking of the generator rotor.

The machine auxiliaries and transformer oil circulating pumps are fed from the 400 V. bus of the unit transformers. The other station auxiliaries and lighting loads are fed from a 400 V.A.C. board situated in the control room and supplied from the unit transformer bus. There is provision for an alternative supply from a stepdown 22 kV/400V trasformer fed from the 22 kV line from Theni which is the main receiving station 35 miles away from Periyar.

The main control board consists of vartical sheet steel cubicles. Each panel has its circuit mimic diagram with automatic semaphore indicators. One panel accommodates the alarms for all the units.

A four panel desk control board of sheet steel is located in front of the main board. The relay panels are separately placed to the left of the main boards. Next to the relay panels are situated the voltage regulator panels with voltage regulators of the B.B.C. type incorporated inside.

To the right of the main control board, the 400V AC board for the station auxiliaries is erected. Next to this is the DC (220 V) board. The DC board is fed from a lead-acid storage battery 220 V. 216 A. H. The battery charging equipment consists of a 24 kW motor generator set with suitable cut outs. A separate cubicle comprising a battery charging selenium rectifier for connection to 400 V. 3 phase AC suitable for trickle charging and high-rate charging is also provided.

The battery room is well ventilated with windows and an exhaust fan. The steel structures are either encased in concrete or painted with anti-corrosive paint.

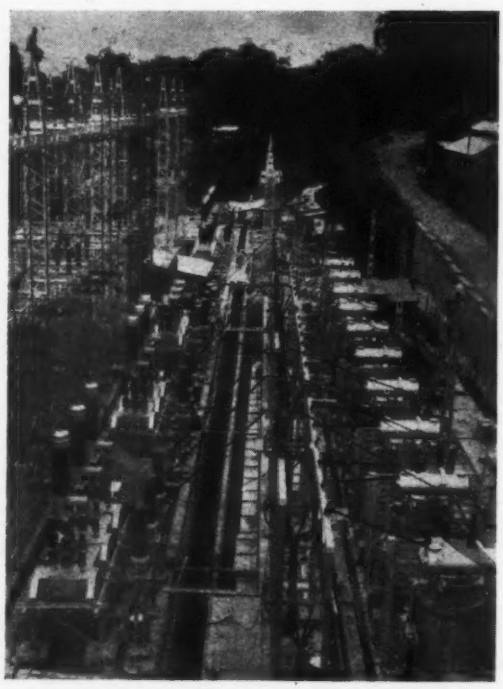
The control gallery was originally proposed to be air-conditioned but deleted later as the favourable weather condition did not justify such installations.

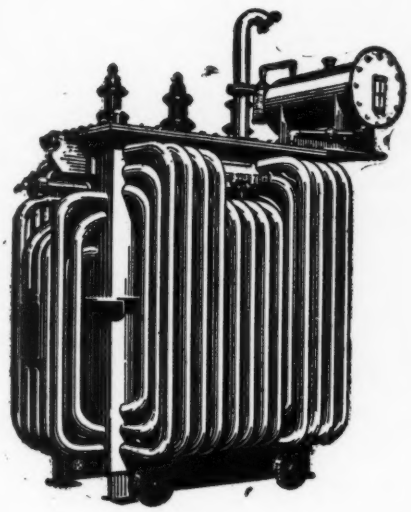
Outdoor station

The layout of the outdoor station is simple as can be seen in fig. 3. The structures are fabricated welded angle steel and galvanised. An extensive networks of overhead earthwires protect the equipment below from lightning strokes. The station has duplicate 110 kV bus bars. Four 110 kV feeders take off from this station, two to Theni receiving station immediately and two to Kayattar in a few months to feed the local industrial loads.

The five 110 kV circuit breakers for the three transformers and two outgoing feeders are of the minimum oil type of ASEA make. The construction breakers are designed to carry a normal current of 600 amps with a rupturing capacity of 2300 mVA at 10 kV; closing

Another view of Transformer yard





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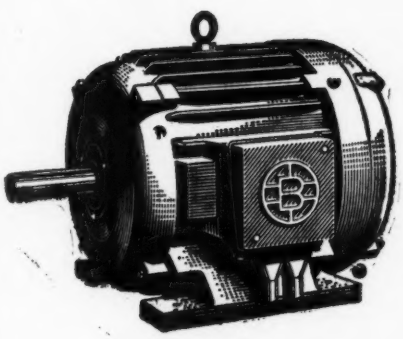

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of these breakers is effected by a spring mechanism automatically charged by a DC motor fed from the station battery. The total opening time is 0.06 sec. The quantity of oil in complete 3 phase set is about 80 gls.

The current transformers with minimum oil are installed external to the circuit breakers.

The 2 sets of 3 phase potential transformers for the 110 kV bus and two single phase potential transformers for the outgoing feeders are also of the minimum oil type. Originally it was proposed to take a tapping from the interconnecting jumpers of the top and bottom bus for the bus potential transformers utilising four 110 kV. A. B. switches. Now one set is connected to the top bus and the other to the bottom bus (see fig. 3) which has resulted in the omission of all four A. B. switches, still retaining the technical advantages of the original proposal.

110 kV lightning arresters ("thyrite" of G. E. make) for the power transformers are erected very close to them for ensuring the best protection. The outgoing feeders are not provided with lightning arresters except for the arcing horns on the approach towers.

In the original sanctioned proposal, thee was provision for a 22 kV substation fed from the 110 kV bus by step-down 3000 kVA transformers, to feed the rural loads around Periyar and to serve as standby to the 400 V auxiliary loads of the station through a 22 kV/400 V transformer. The Chief Engineer for Electricity who attaches great importance to reduce the expenditure wherever possible without affecting the technical requirements, rightly decided to omit this substation and extend the 22 kV line from Theni receiving station to the Power house achieving all the advantages. This decision and other improvements detailed earlier have resulted in a substantial saving during the course of erection of various equipments.

The erection of the complete generating equipment has been done in record time, mainly because no hold up in the programme ws permitted due to the immediate field decisions of the Chief Engineer whenever any difficulty cropped up.

General

An effective earthing net-work has been provided for connecting the indoor and outdoor equipments.

The Power House building is provided with a lightning protective system.

The normal station lighting is from 400V. AC supply. In case of AC supply failure, a DC lighting system is brought into service by an automatic changeover relay.

Telephone and signal systems for communication and indication are provided for the convenience of operation and maintenance.

A power line carrier communication equipment has been installed and interconnected to various important power houses in the Madras State for quick communication.

Continued from page 28

Periyar Tunnel Works

The unexpected rains during the 3rd week of May in 1957 season, while the lining of the leading channel was in progress by the Public Works Department, caused considerable interruption to the works, inside the tunnel, by heavy leakage, past the closed gates at the head sluice. As the programmed work could not be completed as per schedule in 1957, this had to be taken up in 1958 season also by which time, the Departmental regulation gate was erected at the 1st shaft.

Improvement to the tunnel with all the equipments and trained personnel presented considerable difficulties as the work was seasonal and due to other special features of the tunnel.

Total cost of the work was 26.4 lakhs. Labour strength during the peak period was 600 to 800. There were three fatal accidents, two being electrical and one due to slipping of stone from top of shaft.

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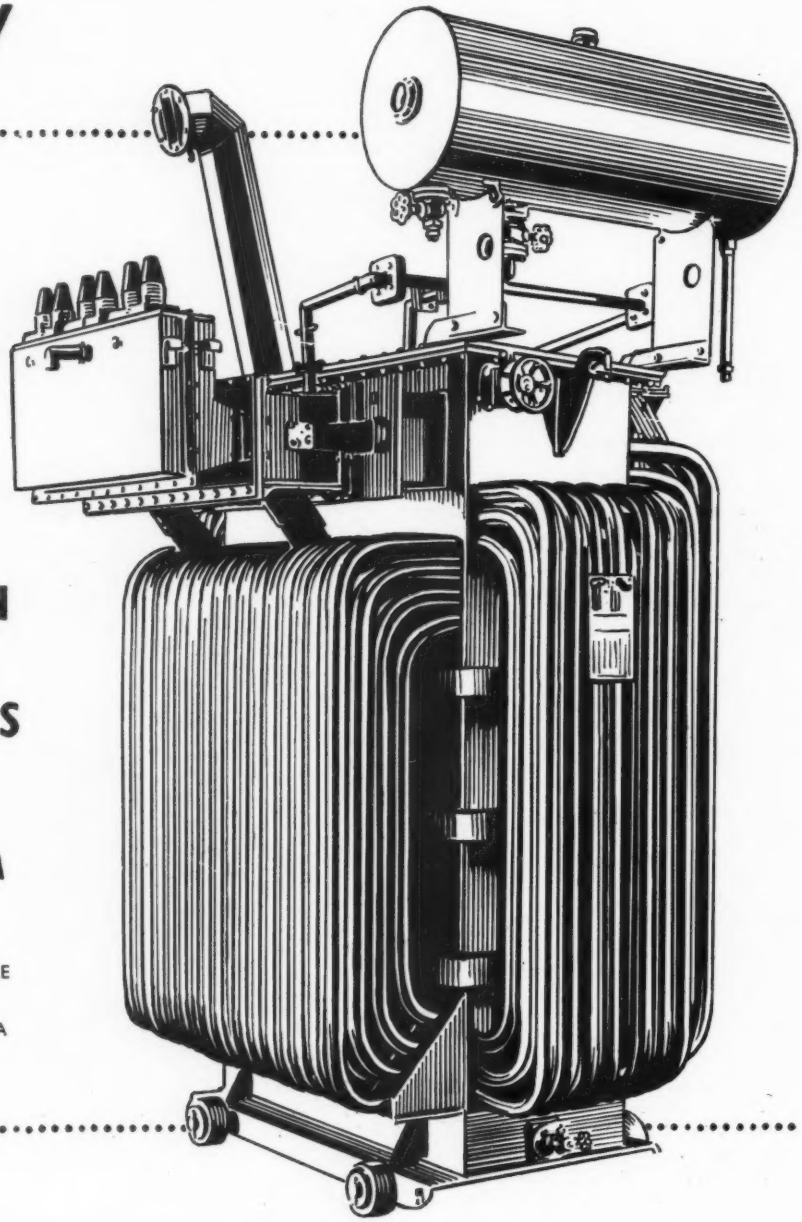

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Periyar Hydro Electric Scheme

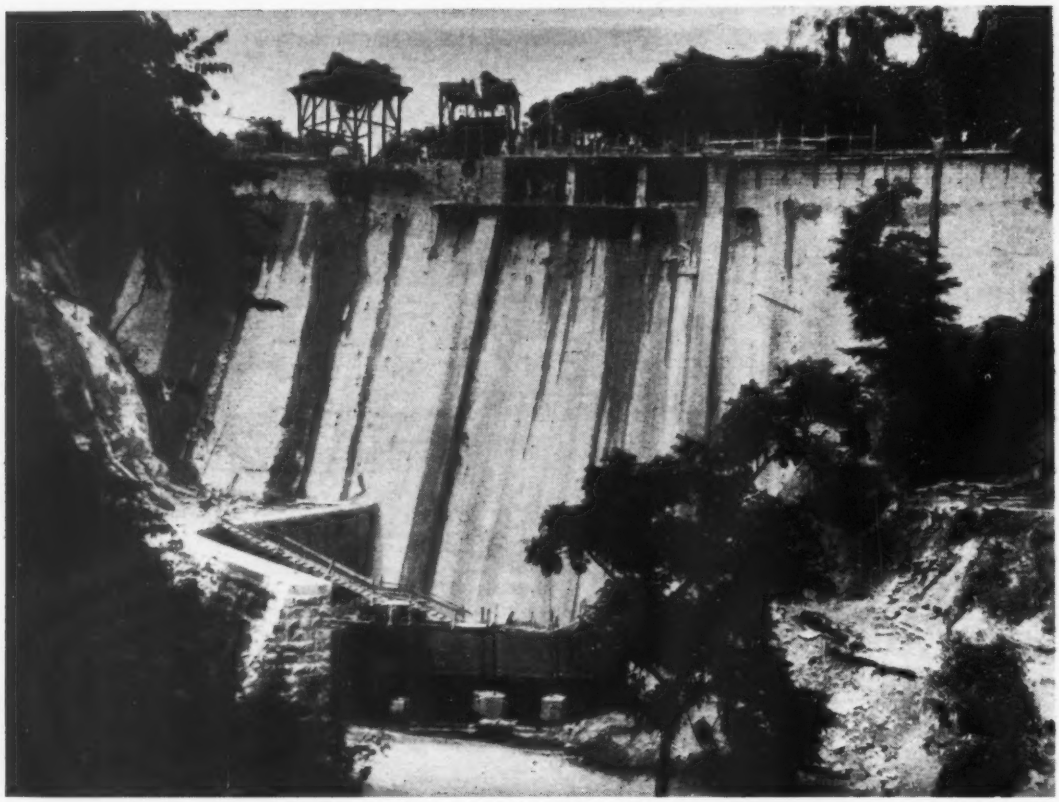
By H. RAGAVENDRA RAO

The Periyar Hydro Electric Project, an ancillary of Periyar Irrigation Project of 1896, after the first detailed investigation in 1928, by the Power Development Wing of the Madras Electricity Department had to be dropped on account of the legal objection presented by the then Travancore Government based on the letter of the deed. This was followed by an arbitration and award. The Madras Electricity Department had to defer the scheme indefinitely. After the dawn of independence, the development of power schemes was accorded top priority. The project was sanctioned under the first Five Year Plan for Rs. 10.48 crores in November 1954, and he execution of the same had stepped into the second Five Year Plan period. The present agreement provided for the payment of royalty of Rs. 12 per kW per year upto 350 million units and Rs. 18 above that limit. The installed capacity of the Power Station is 1,05,000 kW with a firm power of 43,000 kW. for three months during the irrigation closure season in March to May. 3 machines of 35,000 kW. each are to be erected in the initial stage with a fourth unit of the same capacity to be added on in the near future. The scheme is to utilize the potential energy of Periyar waters dropping down through a head of 1260 ft. and feeding each machine with a maximum discharge of 400 cuseces to spin the turbines. This Periyar Hydro Electric Power Station is situated at the foot of the Periyar Hills on the border of the Madras and the Kerala States in Madurai District, on the Madurai-Cumbum-Kottayam Trunk Road, eighty miles from one of the most ancient historic Tamilnad city of Madurai, known for its famous Meenakshi Temple, Tirumalai Nayak Palace and Tamil Academy (Sangam.) One of the three machines of the Periyar station is commissioned and put on bars this day to deliver its juice to serve far and near the citizens of Madras and Kanyakumari near Cape Commorin in the North-East and Southern corners of Madras State through the Madras State Electricity Board grid. A key map of the Grid with the location of the Periyar Hydro Electric Power Station is printed elsewhere.

Before describing the salient features of the project, it is necessary to give a brief narration of the Periyar irrigation system, an uniq ıe project wherein a river which was flowing towards the west and was draining waste into the Arabian sea has been harnessed by a dam in the period 1887-1895 and the water has been diverted to the east through a tunnel to irrigate about 1,30,000 acres of 1st crop and about 50,000 acres of 2nd crop in the Madurai district. This Periyar river that has made fertile the Madurai district once subjected to constant famine and scarcity, runs in the Kerala State over the eastern face of the Western Ghats. In the year 1895, the Madras Public Works Department constructed a dam across this Periyar river at an elevation of 2864 above mean sea level impounding the water in the reservoir called the Periyar Lake which collects a drainage of about 100 inches of annual rainfall from a thickly wooded catchment area of about 239 square miles. The storage capacity of this reservoir is 15,662 m.cft. out of which only 10,000 m. cft. could be utilised usefully for irrigation, through the tunnel due to the level of watershed cutting at 108.5 feet higher than the deepest bed of the reservoir.

The Periyar Dam is a gravity non-overflow type built of uncoursed rubble masonry in lime surki mortar and lime surki concrete. It is 1241 feet in length without the conventional provision of either the expansion joints or the drainage gallery. Its maximum height is 176′ with a maximum base width of 140′. The deepest bed of the reservoir is 2691.0 above mean sea level and the top of the dam is 2864.10 with the FRL at 2861.10. The dam has ten surplus gates of ventway 36′ × 16′ with sill at 2845.10. The water stored is drawn into the tunnel bored at the fringe of the lake, nearly 9 miles from the dam through a watershed open channel and then joins the natural valley, Vairavanar, Suruliyar and finally Vaigai. The water, thereafter, is drawn from the Vaigai into the Periyar main channel from Peranai regulator. The entire cost of the Periyar irrigation project comprising of a dam, water shed channel, a mile long tunnel, a regulator at Peranai, the Periyar main channel and distributaries is Rs. 1.09 crores.

As an extension to the Periyar Hydro Electric



Forebay Dam

Scheme, the Vaigai Reservoir Project is also included under the Madras State first Five Year Plan. In the Periyar irrigation system water can be drawn from the Periyar Lake through the tunnel only during the irrigation season—June to February—to the extent required in the Periyar delta and for the limited drawing capacity of the tunnel. As the effective capacity of the Periyar Lake is rather small, compared to the inflow from the catchment of the Dam. It is now proposed to draw water from the Periyar Lake throughout the year so that the Periyar Power Station will not be seasonal but be a perennial source of supply, to the maximum extent possible, in anticipation of expected inflow into the Periyar lake due to seasonal rainfall and store the same in a reservoir down below. This is the very idea of the Vaigai Reservoir Project wherein the surplus water impounded shall be utilised to irrigate additional 26,000 acres in Madurai and Ramanathapuram districts.

The various appurtenant works of the Periyar Hydro Electric Scheme are detailed here after : Figure 3 explains these details.

Irrigation Tunnel

This tunnel forms part of the Periyar Irrigation Project of 1887-1895. Its length is about 5900 ft. and is termed as the irrigation tunnel, for it was discharging the irrigation requirements of the Periyar delta. It was unlined with a cross sectional area ranging between 90 and 120 sq.ft. and was capable of discharging only 1320 cusecs. From the "History of the Periyar Project" compiled by Mr. Mackenzie, it is gathered that the actual boring of this tunnel was done between October 1889 and October 1894 with only four working faces. As the required power draft is more than the present capacity of this tunnel,

Irrigation Tunnel

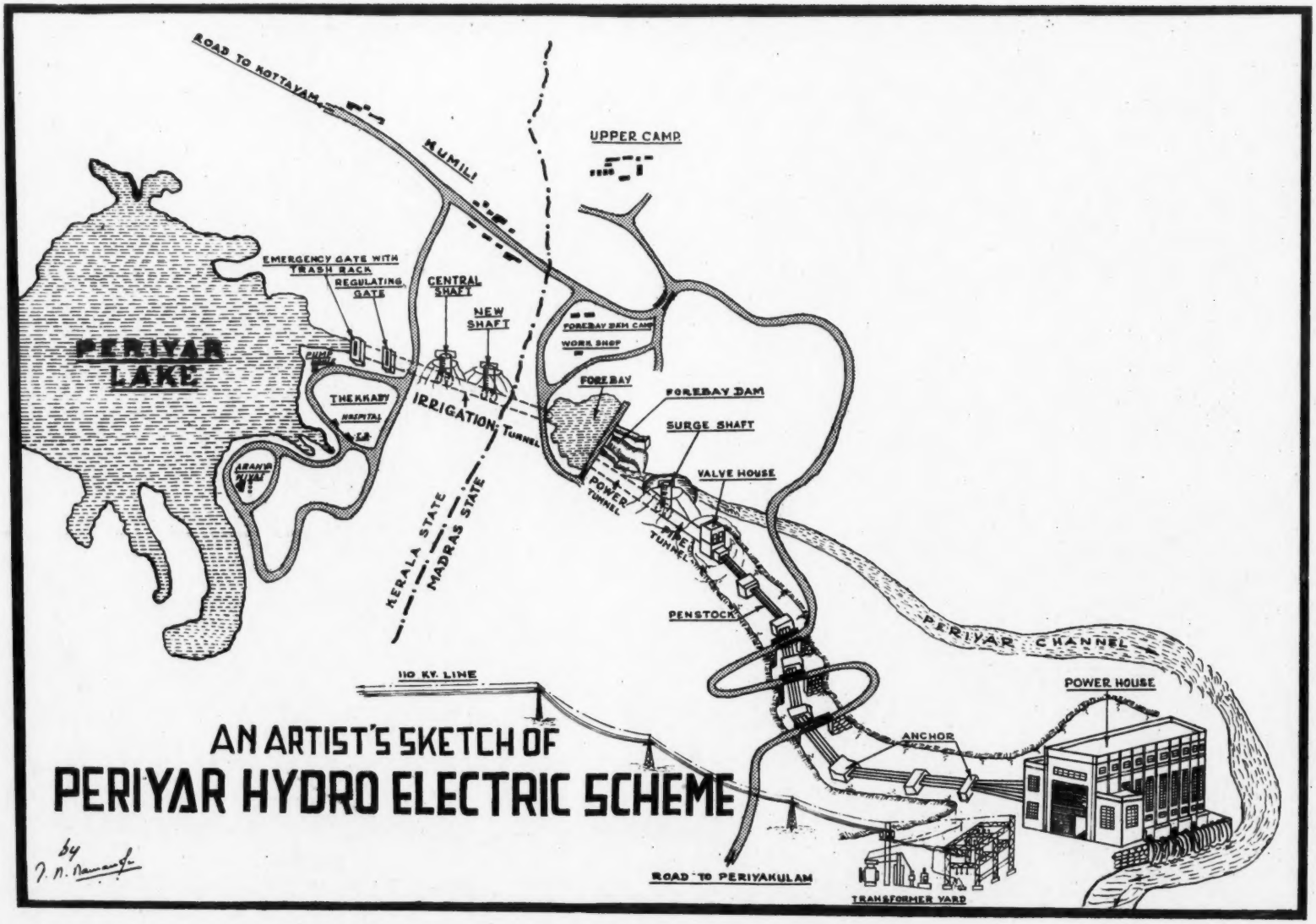

ROAD TO KOTTAYAM
KUMILI
UPPER CAMP
EMERGENCY GATE WITH TRASH RACK
REGULATING GATE
CENTRAL SHAFT
NEW SHAFT
FOREBAY DAM CAMP
WORK SHOP
PERIYAR LAKE
FOREBAY
FOREBAY DAM
SURGE SHAFT
THEKKADY HOSPITAL
IRRIGATION TUNNEL
VALVE HOUSE
KERALA STATE
MADRAS STATE
POWER TUNNEL
PENSTOCK
PERIYAR CHANNEL
110 KV. LINE
POWER HOUSE
ANCHOR
AN ARTIST'S SKETCH OF
PERIYAR HYDRO ELECTRIC SCHEME
by
ROAD TO PERIYAKULAM
TRANSFORMER YARD

Fig. 3

it was decided to enlarge the sectional area and to line it with concrete to the shape of a horse shoe of width 14 ft. and height 12′ 6″ to conform to a finished water way area of 152 sq. ft. for a discharge of 1600 cusecs.

Enlarging and lining of this tunnel could be done only in the irrigation closure season of three months in a year. As the Periyar Hydro Electric Scheme was inagurated in February 1955, four working seasons of 3 months each were available for this work. During this period, the cross sectional area of the entire tunnel was enlarged to about 200 sq.ft. involving a volume of 7,80,000 cft. As time available was not sufficient to line the tunnel to the full length, about 3,500 ft., where the rock was considered to be not quite stable and the portions at inlet and exit was lined with concrete 1:2:4 mix. of about 9″ to 12″ average thickness. In the balance 2400 ft., only a thin layer of bed concrete 3″ to 6″ thick of 1 : 3 : 6 mix. for the floor was laid to obtain smooth stream line flow conditions. The average area of unlined sections exceeds 200 sq.ft. while the lined sectional area is 152 sq.ft. Certain reaches of lined sections were also reinforced with a single row of 1″ dia. rods at 6″ centres. The quantity of concrete laid in the tunnel is 3,27,840 cft. consuming 2,920 tons of cement.

Regulation of discharge through this old tunnel was by means of a pair of Ransom Rapier hand operated gates installed in a specially built headsluice masonry structure at the mouth of the tunnel. The one in the front intended to be an emergency gate was generally kept open, with the rear for regulation of discharge. As these gates erected in about 1900 were fairly old and as the sill of the mouth of tunnel was proposed to be lowered by 4′ 9″ with the approach channel, these two gates had to be replaced. The size of the emergency gate was altered with electric operation and was fabricated and installed at the same old location with modifications in the sluice for the embeded parts by the general superintendent, Public Works Department Workshops, Madras. The position of the regulating gate proposed to be installed by this Department was however, shifted down below from its old location. This hand and electrically operated gate with ventway of 14′ 0″ × 12′ 6″ with provision for remote control from Power House was Manufactured by Messrs. M.A.N. Germany and was supplied by Messrs. Escorts at a cost of Rs. 1.05 lakhs. This was erected departmentally at the upstream face of the first shaft of the tunnel, about 200 ft. downstream of the mouth. It was experimented by the Irrigation Research station, Poondi, Madras, Public Works Department, for the best position of the gate in the shaft. It was found that, with the gate in the downstream position of the shaft, sub-atmospheric pressures prevailed downstream of the gate and when the gate opening was suddenly increased, severe surges travelled in the tunnel and took a long time to damp down. On the other hand, with the gate in upstream position, no sub-atmospheric pressure was observed and surges were of smaller order. This is probably due to supply of air to the tunnel through the shaft in rear of the gate. It was also established in the same experiment that the top of the shafts can be kept open to atmosphere to serve as aeration duct.

Regulating Reservoir

The water, after leaving the exit of the irrigation tunnel flow through the natural valleys, Vairavanar, Suruliyar and finally into the Vaigai. Between the exit of the tunnel and the location of the Periyar Hydro Electric Power Station, the fall in level was more than a thousand feet. The terrain in this reach is very steep and is on rocky bed. The water from the irrigation tunnel is diverted through a new tunnel by contruction of a small dam across Vairavanar below the exit of the irrigation tunnel. A small regulating reservoir with an impounding capacity of 3.10 m.cft. is formed. The storage is just sufficient to supply for about 30 minutes for a peak power draft of 1,600 cusecs, in case of an emergency caused by sudden cut off of supply from the main Periyar Lake.

The location of this dam is skewed to the exis of the irrigation tunnel and at about 400 feet below the exit of the tunnel. It is a gravity masonry dam with central spillway of length 45 feet, a non-overflow section of 132 ft. on the left side and 111 ft. on the right side. The length of about 288 feet at top is divided into three blocks with two contraction joints of the conventional type. The spillway has again three spans of 13′ 8″ with two piers in between, of 2 feet width. The crest of spillway is at 2820 MSL, while the top of dam is at 2829. The rear slope of the spillway is 0.8 to 1 and is tangential to the profile of the crest at top and also to the concrete bucket with a radius of curvature of 23 feet. The maximum depth of overflow is about 5 ft. for a discharge of 1900 cusecs. The spillway has no shutters and has a R.C.C. decking footbridge, 8 ft. wide at 2829 above M.S.L.

The irrigation scour sluice of size 10 feet by 8 ft. with sill at 2732 is provided and controlled by a gate and is intended for purposes of releasing additional water whenever the irrigation requirements are in excess of the discharge through the Power House and also during unprecedented floods. This will also be used for clearing silt and colloidal matter in the reservoir. For release of water for power purposes, a 13 feet diameter pipe sluice with a gate and trash rack is provided on the right flank in the non-overflow section of the dam. The pipe sluice of 87 feet in length is transitted from the rectangular section of the gate frame, and is connected to the concrete lines horse shoe shaped pressure tunnel 14 feet wide and 12′ 10″ high with a suitable transition from circle of 13 feet diameter to horse shoe, in a length of 40 feet. The gates for these two outlets with electrical and hand operated hoisting equipments and the pipe sluice, were manufactured by Messrs. M.A.N. Germany and supplied through their Indian agents Messrs. Escorts at a cost of Rs. 5.12 lakhs. Erection of these was done by Departmental engineers.

Geology of the Dam Site and Fault Zone Treatment

Before taking up the construction of the Dam, a few exploratory core drill holes on the left flank were done to find out the nature of the substrata for the design of the foundation. The probable rock line along the

axis of the dam was mapped out and in general, it was revealed that sound rock could be met with at a fairly reasonable depth on the left flank while the natural ground surface on the right flank showed visible hard rock. Therefore, geologically, the site was found suitable for a dam of 100 ft. height. During actual excavation of foundation in March 1956, contrary to this expectation, a fault zone of width varying from 10 to 15 feet containing an admixture of reddish material with crushed rock dust was met with in the bed of the channel and stretching across the width of the dam, upto ch. downstram 125 beyond the bucket apron of the spillway.

The dental treatment of weak zones in foundations dealt with in Chapter 9, Gravity Dams—Design Supplement No. 2, Vol. X, Design and Construction Reclamation Manual of United States Bureau of Reclamation, was generally followed to treat this fault zone. The soft soil all along the seam was scooped out for varying depths and was plugged with 1 : 2 : 4 cement concrete. At the front portion of the seam, a deep cut-off well for the full width of seam plus 2 feet on either side and 10 feet below adjacent cut-off trench was excavated and plugged with 1 : 2 : 4 cement concrete. Two rows of grout holes were drilled into this plugged well to about 20 feet below its bottom and were grouted. Another series of holes to form a curtain in the rear of the seam were also drilled and grouted. With this treatment and plugging with concrete in the heel trench, the Percolation factor (the path of percolation along the surface of contact between the foundation concrete and ground surface divided by the head) was arrived at 2.20. As United States Bureau of Reclamation Manual prescribes a factor of 2.5 for such seams, the following additional treatment was therefore done in the next 1957 closure season.

(*a*) Consolidation of soil of the seam by drilling and grouting on the upstream heel trench.
(*b*) Forming a new cut-off trench further upstream, 25 feet deep across the channel bed keying into hard rock on either flank and plugging the same with concrete upto channel bed.
(*c*) Extensive drilling and grouting the bed of cut-off trench and also the flanks.

In consequence of the above treatment, the percolation factor increased to 3.95.

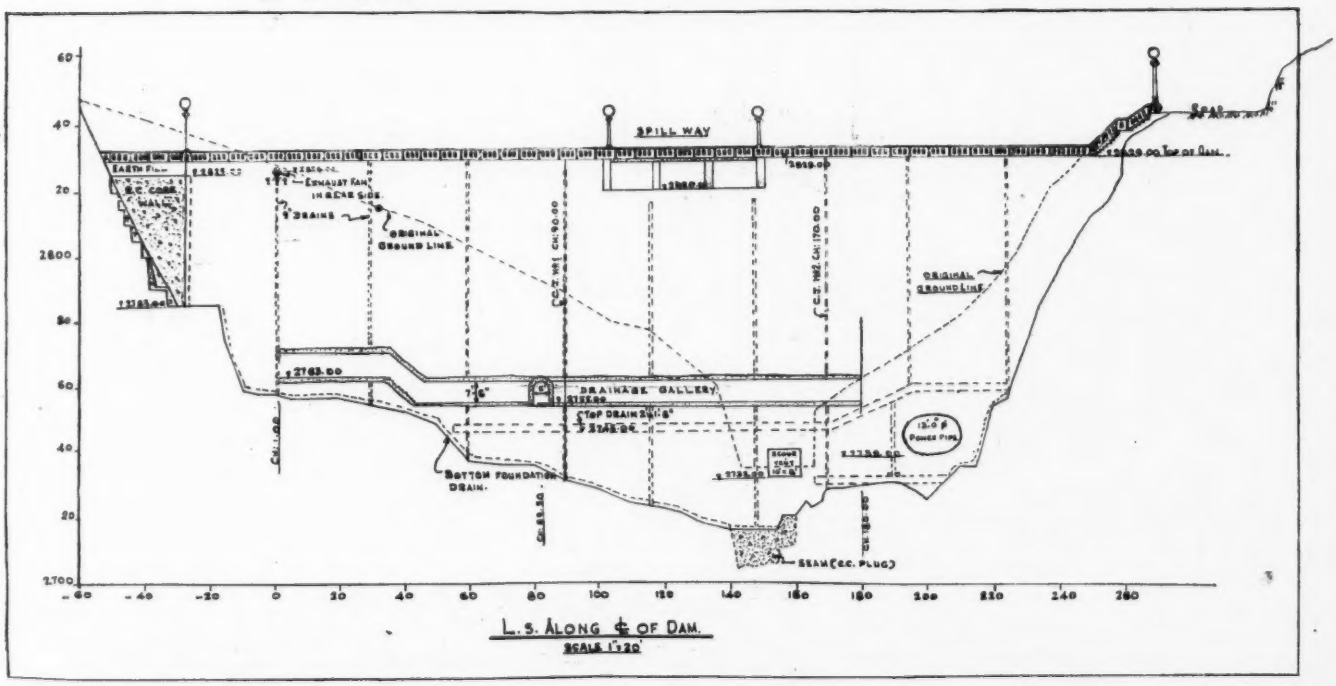
In addition to all the above, a series of holes on the upstream of dam were drilled to varying depths and grouted with a chemical solution of hydrochoric acid and sodium silicate.

Structural Design Features

The dam designed as solid gravity type with generally accepted practice of avoiding tensile stress in masonry and the middle third rule for both conditions of the reservoir (empty and full). The weight of masonry was assumed as 149 lbs. per c.ft. and 50% uplift was allowed at all joints. The standard practice in regard to sliding friction by keeping the tangent of the angle of the resultant with the vertical at less than 0.75 at all sections was also adopted.

Inspection Gallery

An inspection gallery of size 5′ width and 7′ 6″ height was provided along the length of the dam for



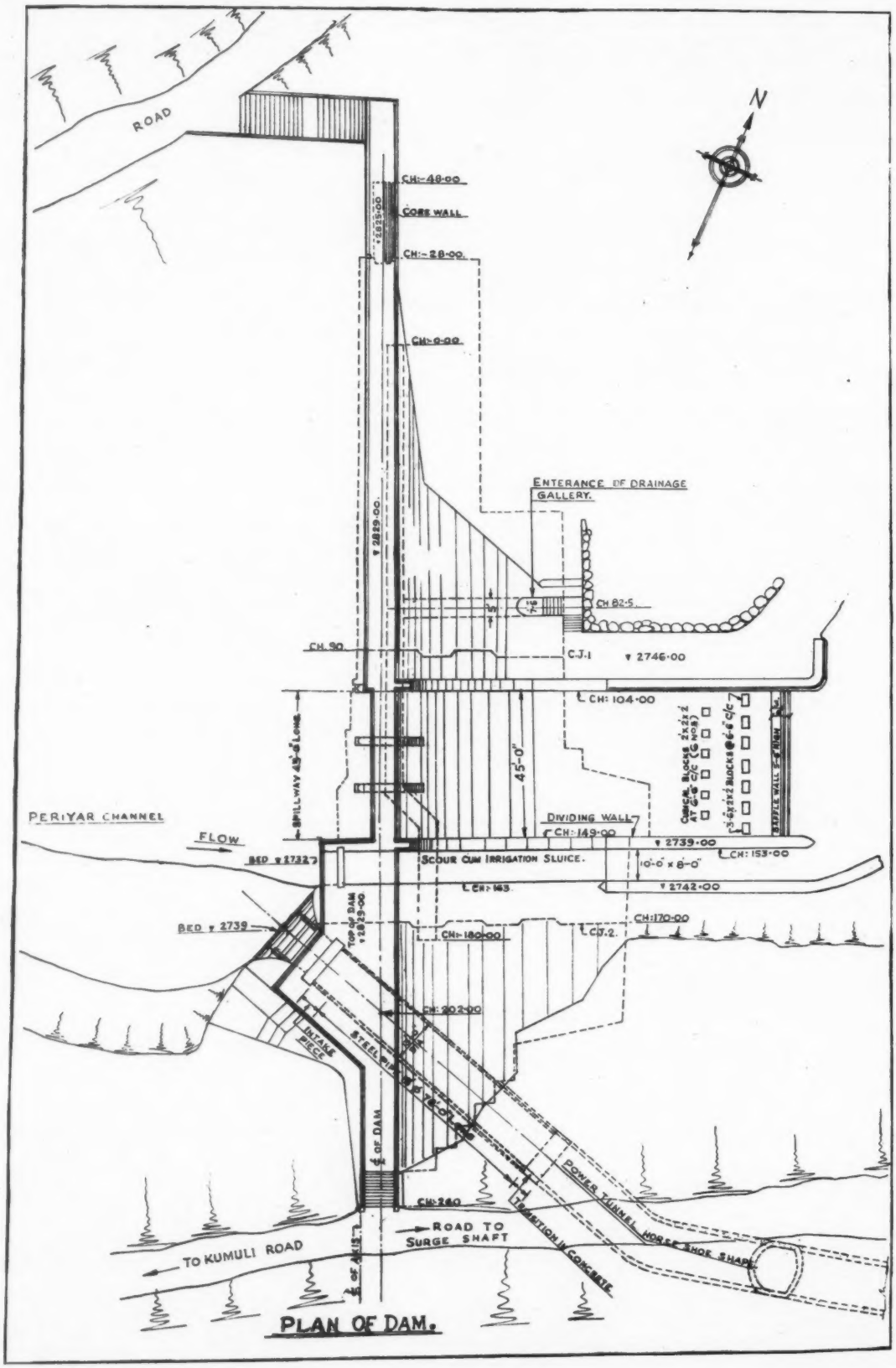

ROAD
N
CH:-48-00
CORE WALL
CH:-28-00.
CH:-0-00
ENTERANCE OF DRAINAGE GALLERY.
CH 82-5
CH. 90
C.J.1
CH: 104-00
SPILLWAY 45'-0" LONG
45'-0"
DIVIDING WALL
CH: 149-00
PERIYAR CHANNEL
FLOW
BED ▼ 2732.7
SCOUR CUM IRRIGATION SLUICE.
CH: 153-00
CH: 163
BED ▼ 2739
TOP OF DAM ▼ 2829-00
CH: 180-00
C.J.2.
CH: 170-00
CH: 202-00
INTAKE PIECE
STEEL LINING
CH: 240
POWER TUNNEL HORSE SHOE SHAPE
TRANSITION IN CONCRETE
ROAD TO SURGE SHAFT
TO KUMULI ROAD
PLAN OF DAM.

Fig. 4 (b)

180 feet. This is connected to a cross gallery across the width of the dam, through which approach to the gallery from the left flank is formed. An exhaust fan is also provided on the left flank for eliminating entrapped air through the vertical shafts from the roof of the drainage gallery. [Figure No. 4(*a*) & (*b*)] will explain the general details of the dam.)

Power Tunnel, Surgeshaft and pipe tunnel

A brief description of the Power Tunnel, surge shaft and pipe tunnel is covered in the following paragraphs. The work on these was executed in a period of about 2½ years by Messrs. Patel Engineering Co. Ltd., Bombay, to whom the work was awarded on competitive tenders.

Geology

During preliminary investigation, exploratory borings were made at the position of the drains along the alignment of the power tunnel. These revealed that along the entire length of the tunnel good granite rock could be met with. The alignment of the tunnel crosses six drains on the surface. Sheet rock was visible in the area of three drains and at other drains excellent rock was available below overburden ranging between 10 to 40 ft. Minimum rock cover over the crown of the tunnel was seen to be 20 ft. and

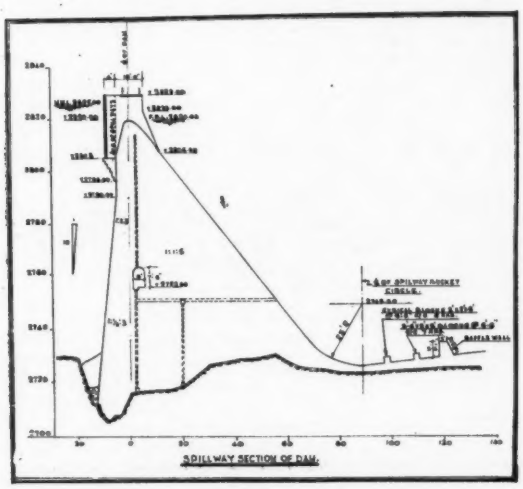


Fig. 4 (c)

a maximum cover of 100 feet was also available. The report of the geological survey of India further concludes that in driving a tunnel in this granite rock no major seepage of water involving heavy pumping or geological problem will be encountered. As regards the surgeshaft sheet rock would be available in the area within ten feet below surface and the major portion of the shaft shall be in sound granite rock. Almost similar type of soil was expected in the area of pipe tunnel also.

During actual excavation it was seen that the geological forecast was quite sound and the entire excavation was in good granite rock except in a short reach of about a hundred feet in the neighbourhood of the first drain where soft rock was met with requiring temporary steel ribs and timber supports to retain the crumbling of soft rock pieces. Subsequently, the cone formation of the strata was able to stand by itself without the supports. Due to the existence of the drain, seepage water was dripping heavily, Particular care was excercised to fill in these pockets during lining. A series of holes were drilled for about fifty feet on either side of the drain at ground level and grouted to consolidate and reduce pressure of seepage water over the tunnel lining.

Details of Work

The power tunnel is completely concrete lined to a horse-shoe shape, 14′ wide and 12′10″ high. Its length is about 4,000 ft. including the 87 feet pipe sluice embeded under the body of the dam. Out of 4,000 ft. 600 feet are lined with R.C.C. The tunnel heading was tackled through two adits and one end, offering four working faces and actual driving was got through between 15.7.55 and 20.4.56 in hardly nine months involving about 9,00,000 cft. or rock blasting and muck removal. Electric detonation for blasting was adopted and adequate ventilation with electrical exhaust fans was provided. Concrete lining of the tunnel was done by hand placing for invert and sides upto springing level and pneumatic placer for arch.

Surge Shaft : The surge shaft is of 40′ internal diameter and 140′ in depth. Excavation of shaft was through hard granite rock and was sunk from the top except the bottom 12′ to 15′, which was excavated through the adit driven for power tunnel excavation. No major problem was met with. The side of the shaft were lined with reinforced cement concrete of mix 1 :1½:3 with 1″ graded metal and a single row of reinforcement 5/8″ at 9″ centre to centre and at 1′ centre-centre vertically. The reinforcement was placed at 6″ from the finished face. The minimum thickness of 12″ for lining was specified with an overbreak of 4″ for purposes of payment for excavation and concrete lining. It may be of interest to mention in this context that the actual depth of overbreak was about 6″ beyond the neat line of excavation. The sinking of the shaft involving blasting of about 2,03,000 cft. was got through in a period of five months between Oct. 1955 and February 1956. The floor and sides of the shaft were also grouted.

Two penstock pipes of diameter 10 feet take off from the surge shaft. These pipes are erected in the pipe tunnel of length 190 feet.

Valve House and Penstock

From the downstream side of the surge tank, two meter 10′ dia pipes with a hydraulically designed intake piece at their mouths take off. These two pipes are located in a concrete lined pipe tunnel referred to earlier. Each of these two 10′ dia meter pipes bifurcate into two arms of 6′-6″ diameter through a special manifold piece. The four branches emanating from the two manifold pieces are connected to four 78″ dia meter penstock lines through four butterfly valves. Under the first stage of the Periyar Hydro Electric Scheme, only the three penstock lines are connected upto the machines while the fourth penstock with its

Pen Stock Line

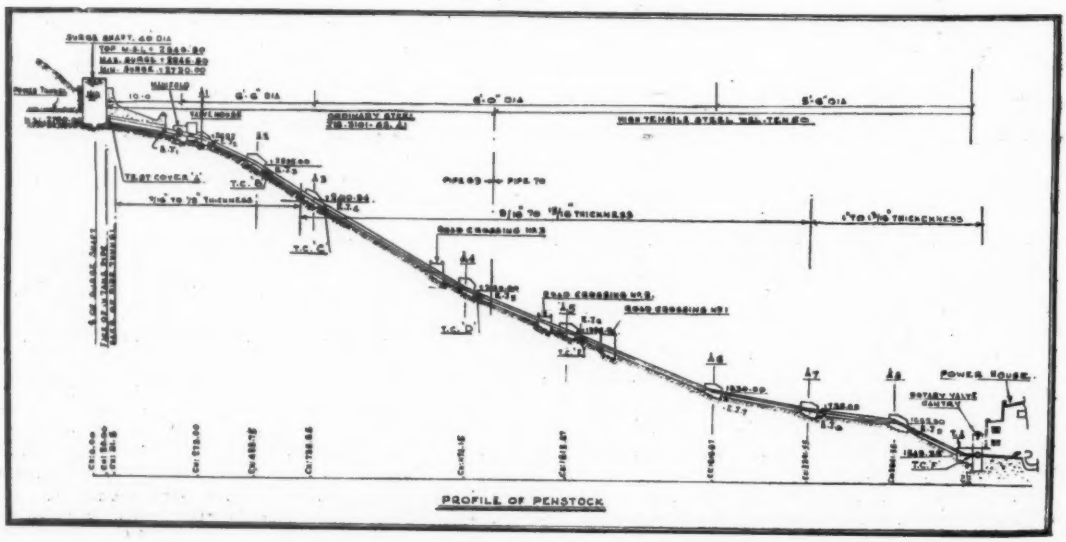
butterfly valve is laid upto the first anchor and at its end, a dish-shaped blank cover is provided. Each of the 78″ diameter penstocks converges into 72″ and 66″ at Power Station end from where a special reducer 66″ × 45″ connects the pipe to a high pressure rotary valve of 45″ diameter. The slopping length of the penstock 120″/78″/72″/66″ is about 350 ft. In a horizontal distance of 3127 feet the drop is 1,161 feet which works out to a slope of 1 in 2.7. The enclosed profile of the penstock (figure 6) with its various anchors, thickness and diameter, type of material of pipe will explain the various details. Including the manifold and terminal anchors, there are ten anchors in all. While the intermediate and manifold anchors are common for all the four penstocks, the terminal anchor is independent for each of the four penstocks running parallel from top to anchor no. 8, and then diverge out to suit the locations of machines at Power Station. Although only three penstocks have been laid now, the foundations for anchors for the fourth line also have been laid.

The Penstocks, valves etc. were supplied and erected by M/s. Sakai Iron Works Co. Ltd., Osaka, Tokyo, Japan. All the pipes and accessories were despatched from Japan in three ships—first in October, 1956, and second and third shipment in February, 1957. The erection was started by the end of January, 1957 and completed by December, 1957.

Type of pipes materials etc : The material of the pipe in the top reaches upto 270 feet below anchor no. 4 is of Japanese ordinary steel JIS.3101—SS.41. with ultimate breaking strength of 58,320 to 71,120lbs. per sq. inch and yield strength 32,710 lbs. per sq. inch and that in lower reaches it is of Japanese high tensile steel 'Welton 50" with an ultimate breaking strength 71,120 to 82,490 lbs. per sq. inch and yield strength 46,930 lbs. per sq. inch. The pipes are of welded construction and are received in lengths of 18 feet except the 120″ diameter pipes which were received in the form of shells. The field joints were welded at site by Japanese Welders. The intake pipes at the mouth of the 10 ft. diameter pipes in the shaft and manifold formation for reduction of 10 ft. diameter to 6′-6″ were received in fabricated segments and were welded at site after erection and alignment.

Anchorages : In accordance with the customary procedure, anchors are provided at all angle points. The anchors are so designed that they will, by gravity alone, withstand the resultant of all hydrostatic forces under the following conditions (1) for 3 second closure of the machines ; (2) for one second closure of the machine ; and (3) for bursting condition of the pipes. For condition (1) the final resultant falling within the middle third of the base of the anchor and for conditions (2) and (3) the final resultant falling within the base of the anchor were ensured in the design. Except a few anchors which were founded on hard rock all the others are on hard soil and soft

Fig. 6



Anchor No. 4—Superstructure

rock. The maximum pressure on the base of the anchor due to all hydrostatic forces was limited to the bearing capacity of the particular soil met with in the foundation. Field tests for bearing capacity of some representative soil were conducted. The anchors were formed with 1 : 3½ : 6 cement concrete of 1″ graded metal and reinforcement with 3/4″ diameter M.S. rods was also provided. The penstock pipes were supplied in lengths of 18 feet and one pier for each pipe at about centre was provided. The piers were designed to take care of all the hydrostatic forces by its own weight and the final resultant of all forces under conditions of expansion and contraction of the pipe, falling within the middle third of the base was ensured. The maximum stress on the base was also limited to the bearing capacity of the particular soil met with in the anchor.

Expansion Joints: Fig. 6, profile of the penstock shows nine expansion joints in each of the penstocks. In conformity with the usual convention, the joint was provided at the top of each section just below anchor except for the 10 ft. diameter pipes, which is located on the lower end of the reach and above the manifold anchor. The joint is of the usual slip type with an allowance for about 10″ to 12″ variation due to expansion or contraction.

Manholes: To facilitate access into the penstock for inspection purposes, nine manholes of 20″ internal diameter have been provided. The positions of these are on the downstream and near about the nine expansion joints and except at anchor no. 1 they are placed at the bottom at an agle of about 45°.

Transport and Erection:The 78″,72″ and 66″ diameter pipes in lengths of 18 feet were packed by telescoping with double or triple nesting, of pipes, so as to occupy less shipping space and well tied gogether to prevent slipping. These were shipped from Japan and received on Madras shores. From Madras to Theni, - the nearest railhead 34 miles from the project - they were railed by metre gauge waggons. The pipes were unloaded at Theni with the help of an overhead and hand opeated travelling 25 ton crane and 22 RB mobile crane. To reduce the weight for road transport, the double and triple nested pipes were denested in most of the cases and were transported by lorries, trailors and unloaded by hand or by the 38 RB mobile crane directly on penstock slopes or stacking yards at three pre-determined locations near the slopes. A 45 lbs. rail track metre gauge run on wooden sleepers was laid along the penstock slope in the grading space of the future fourth pipe line from manifold anchor down to terminal anchor. Two electrically operated 50 HP single drum haulage winches - of Hitachi Ltd., Japan - one at the top of penstock slope and the other at anchor no. 6 were erected and used with suitable metre gauge flat trucks for haulage of the pipes to the slope from where they were taken to the respective positions by chain block and tackle during actual erection. At the head of the penstock below anchor no.1 a fixed overhead gantry with a travelling hand opeated 10 ton chain block was erected across the the penstocks for transhipment of pipes from the road terminus to the haulage truck on the opposite side. Erection of bends at anchors was taken up first and the pipes on the upstream side were then erected upto the next upper anchor. Each section was thus erected and finally they were joined by the special expansion joint piper. All the field joints were welded at site by Japanese technicians with the help of hand arc welding machine provided free of charges by Messrs. Sakai Iron Works Ltd., Japan, as per terms of contract. In workshop each pipe consisting of three rings and all longitudinal and circumferential seams inside and outside were welded completely by use of Union Melt Arc Welding machines of maximum current capacity ranging between, 1200 Amps and 2,000 Amps. After field welding of circumferential joints,the inside was gouged and final welding was done.

Hydraulic Tests: One of the field tests for the erected penstock was to examine the watertightness by filling the pipes with water and applying the specified pressure with the use of a hydraulic pressure pump. A brief outline of the procedure adopted for this hydraulic test is described below:

The entire penstock was sectionalised into five reaches by introduction of six test covers, the one at top and bottom being dish shaped and the intermediate ones being of flat plates stiffened by R. S. joists. While the dish shaped covers A and F (vide Fig. 6) were welded to the pipes, the others were inserted and bolted between the expansion joint pipe and the top fixed piece by pushing down the insert piece of the joint. The positions of these test covers is shown in the profile drawing. The test pressure was limited to 1.75 times the static head in the reach A to C and E to F and 1.65 time in the section C to E. The intention of reducing the test pressure in the section C to E from 1.75 to 1.65 was to limit the developed stress in the pipe to 0.80 of the yield stress of the material.

Painting (a) at shop: After fabrication and annealing, all pipes were cleaned by sand blasting and also by the use of air injection or centrifugal type blaster. The outside surface was painted immediately with two coasts of red lead (synthetic red lead Dai Nippon Toryo Co., (Japan and the inside surface was painted with one coat of bitumastic anticorrosive solution (Wailes Dove Bitumastic Co., England) and two coats of liquid bitumastic enamel (Usagida Chemical Works Ltd., Japan. The two edges of the pipes to be joned in the field were left without painting.

(*b*) *at field*: After erection. the inside surface was given one coat of liquid bitumastic enamel and the outside surface one coat of aluminium paint (Shinto Paint Co., Japan). Painting was done both by hand and by air spray guns.

Power Station Building

General: This building—designed to house four generating sets of 35,000 kW capacity each – is a steel framed structure of inner diamentions 200′ × 64′6″ enclosed by masonry walls and covered by reinforced cement concrete roof slabs. It consists of a machine hall of width 43′-6″ and an annexe of width 21′-0″ but of the same length formed in ten bays of 20 feet. The former is a single storeyed structure while the latter has a first floor for accommodating the control gears, battery room and other equipments. On the rear of the building, a tail race pool of width 24′-6″ is formed with a masonry weir to lead the tail race water from the machines to spill over it and join the natural watercourse, the Vairavanar.

Steel Structure: The steel structure essentially consists of three rows of stanchions—eleven in each row, with corresponding longitudinal and cross girders, filler joists for two floors and truss members for two roofs.

The machine hall stanchions carry crane girders for traverse of a 100 ton electrically operated overhead crane. It also includes two sets of two stanchions for fixing two rolling shutters and also an annexe on the north side with stanchions and girders for a small pump house. These were fabricated in the workshop of Messrs. Bardoni, Italy under supervision of Messrs. Societa Anonima Electrificazione, S. P. A. Milano, Italy and supplied by M/s. S. A. E. (India) Ltd.

The steel work is fabricated with rolled sections of metric size for roof filler joists and angles for roof trusses. The stanchions and beams of large size are formed by welding steel plates with an automatic process, except for the crane gantry girders which are subject to variation, are of rivetted construction. The total weight of the steel frame as supplied including two staircases and hand rails is about 324 tons. Erection of these was also entrusted to Messrs. S.A.E. under the supervision of an Italian erector and local labour. The contract was entered into in December, 1955 with a mandate to complete the entire work by end of April, 1957. The Suez Canal trouble interrupted early supply and the work could be completed only by end of October, 1957.

Figure 7 shows a cross section of the Power Station showing the steel structure.

Power Station Machinery and Equipments.

(*a*) *Hydraulic Turbines and Accessories*

Global tenders were invited for alternative supply of impulse and reaction turbines to generate an output of 50,000 BHP at 300 or 600 RPM under a nett head of 1215 Ft. The tender. of M/s. J.M. Voith, West Germany represented by Messrs. Protos Engineeering Co., Ltd., Bombay contained three alternatives (*i*) Impulse 300 RPM (2) Francis Spiral 600 RPM and (3) Francis Spiral 750 RPM. Alternative no. 3 being the least expensive, giving the best efficiency, was accepted, though it involved installation of the unit at a slightly lower elevation and an order for three such turbines along with three high pressure rotary valves was placed in December 1955 atan approximate total cost of about Rs. 24 lakhs. It is to be pointed out that reaction turbines for a gross head of 1296 ft have been installed for the first time in India.

The manufacture and delivery of the machinery had been kept up promptly as per terms of contract. The built-in-parts of the turbines comprising of three draft tubes and three relief valve liners were shipped in January 1957 and were at site by May 1957. The first turbine with its high pressure rotary valve was shipped by end of July 1957, and was at site by end of November 1957. The second and third units were shipped in October 1957 and January 1958, and received at site in January 1958 and April 1958 respectively. The salient features of the turbines are detailed below:

1.	Type:	Vertical shaft re-action Francis.
2.	Normal speed:	750 RPM,
3.	Maximum output under a nett head of 1225′	50,000 BHP

Erection of the first turbine was commenced in December 1957 by one works-trained Indian Engineer who was later, in January 1958, replaced by a German chief erector followed by another German assistant in February 1958. It is expected that all the three units will be completely erected before the end of this year.

(*b*) *Generating equipment and accessories*: M/s. A.E.G. Berlin, West Germany represented by Messrs. Dodsals Ltd., Bombay offered eight alternatives for the alternator with speed ranging between 300 and 750 RPM and runaway speed ranging between 530 and 1375 RPM and flywheel effect of 8.04 × 106 lbs/sq. ft. to 1.05 × 106 lbs/sq.ft. The alternative design to suit the type of turbine by M/s. Voith was accepted and an order for three units with indoor switchgear excluding cables at an approximate total cost of Rs. 45 lakhs, was placed in February 1956.

The supply of equipment under this contract had not been upto the expectation contemplated in the contract for various reasons, arising out of correspondence for approval and decision of technical features of the alternators and auxiliary equipments. Mr. V. P. Appadurai, Chief Engineer for Electricity had to fly to Germany in January 1958 for personal discussion and to expedite supply of the first unit. His personal contact with the Board of Management of Messrs. A.E.G., Germany had the desired effect and the delivery was advanced by ten weeks. Shipment of the first unit was effected in March/April 1958 and was received at site by the end of May/June 1958.

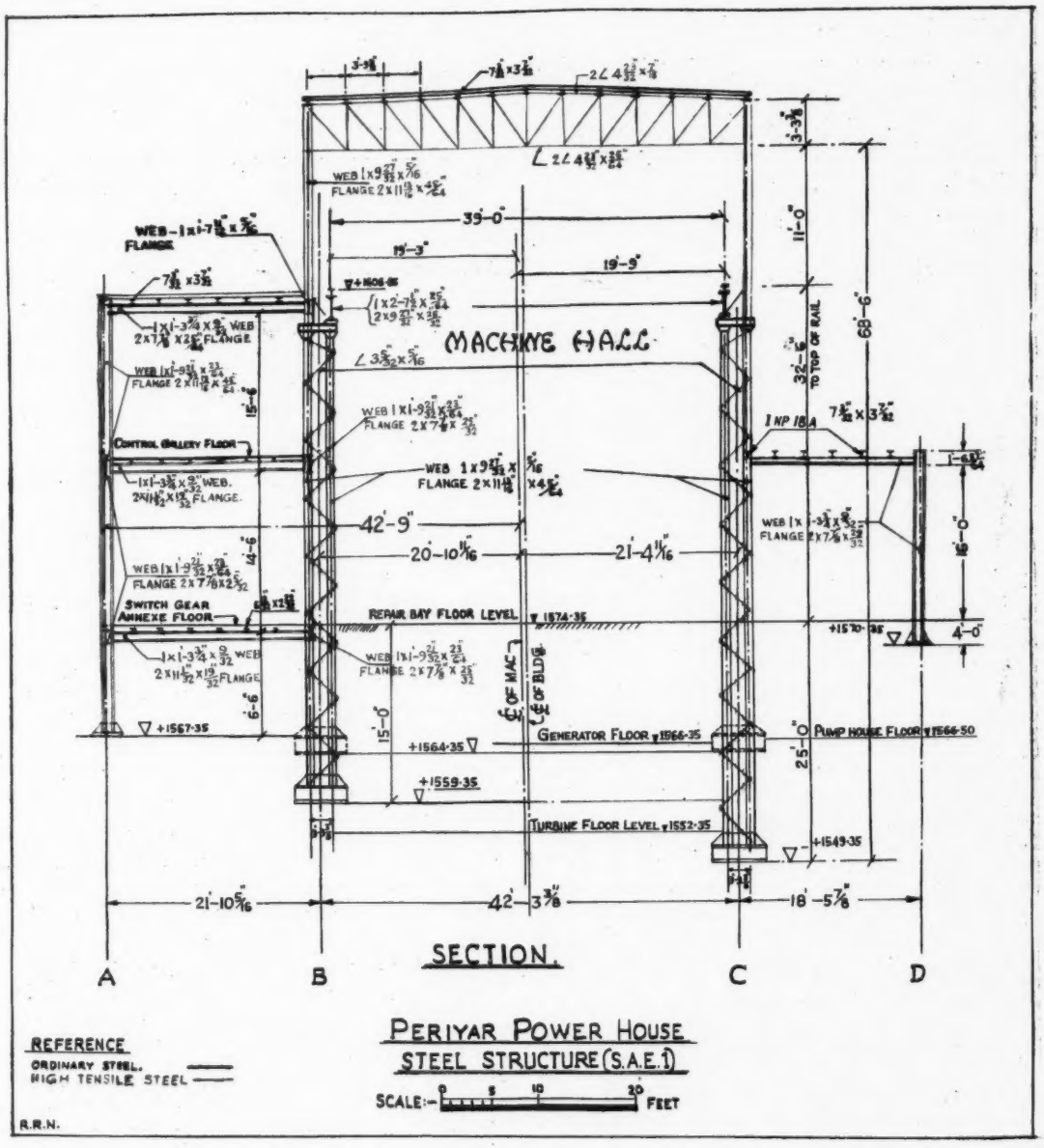

MACHINE HALL
SECTION.
PERIYAR POWER HOUSE
STEEL STRUCTURE (S.A.E. 1)
REFERENCE
ORDINARY STEEL
HIGH TENSILE STEEL
SCALE:- 0 5 10 20 FEET
R.R.N.
A
B
C
D
39'-0"
19'-3"
19'-9"
42'-9"
20'-10 11/16
21'-4 11/16
21'-10 5/16
42'-3 3/8"
18'-5 7/8"
REPAIR BAY FLOOR LEVEL +1574.35
GENERATOR FLOOR +1566.35
PUMP HOUSE FLOOR +1564.50
+1564.35
+1559.35
TURBINE FLOOR LEVEL +1552.35
+1549.35
+1567.35
+1570.35
CONTROL GALLERY FLOOR
SWITCH GEAR ANNEXE FLOOR
INP 18A
TO TOP OF RAIL
69'-6"
11'-0"
25'-0"
4'-0"

Fig. 7

The generators were :

1. Type .. Vertical
2. Speed .. 750 R. P. M.
3. Maximum voltage 11,000 v $\begin{cases} +1000 \text{ v} \\ -2000 \text{ v} \end{cases}$
4. Rated output .. 41,200 kVA 0.85 P.F.

Erection of the first unit was st rted by middle of June 1958 by three German erectors. On this day, the first unit is commissioned and the other two units are programmed to be commissioned to augment the resources of the Madras State Electricity Board grid before the end of this year.

(c) *Main Transformers*: The generated voltage of 11,000 volts is stepped up to 1,10,000 volts by installation of a bank of three single phase transformers of capacity 14 mVA for each generator. The transformers which were shipped without oil and outer fittings and filled with nitrojen gas are direc'ly connected to the generators without any intermediate circuit breakers or switch. They are oil-water cooled type connected delta/star with neutral point of 110 kV. solidly earthed. For nine units, one complete transformer is kept as spare.

For protection against fire, water spray protection system by use of a compressor plant is also provided. Reinforced cement concrete partitionwalls are also provided in between the transformers.

These ten single phase transformers were supplied by Messrs. Oerlikon Englineering Company Switzerland. The first unit was shipped in February 1957 and the last in September 1957.

Frection of these was done under the direction of the departmental Divisional Engineer (electrical) and a Swiss works trained engineer had this checked up before commissioning.

Indoor Switchgear and control panels. The main 11kV switchgear consists of metal clad cubicles for control of the generators. Space for a similar cubicle to be erected later for the fourth unit is also provided. This receives the outgoing leads from the machine in a special duct and connects to the step up 11/110 k.V Power transformers and also provides for busher leads to the station service transformers (Clophen filled) located adjacent to the cubicles. Neutral switchgar in cubicles is also mounted adjacent to the main II k.V. switchgear.

The D. C Board in the control gallery is fed from a lead-acid storage battery 220 V 216 Am. housed in a well ventilated room with an exhaust fan etc., at the western end of the control gallery floor. A 23 kW motor generatar set with cutouts and a separate battery charging rectifier are also provided.

(e) *Outdoor switchgear and Transmission system*:

The 110 kV outdoor station consistes of an elevated galvanised steel structure of double deck type with two sets of busbars and the necessary isolating switches. The structure accommodates five minimum oil circuit breakers of ASEA make (with provision for one future) including Nos. for the double circuit 110 kV line to Theni. The structure is extended to house two breakers for the Kayathar 110 kV double circuit line. The following 110 kV transmission lines take off from the structures.

1. One Double circuit line to Madurai via Theni.	80 miles (completed)
2. One Double circuit line to Kayathar via Rajapalayam	100 miles (under construction)

The latter is mainly intended to feed a Caustic Soda Ash plant in Arumugane i in Tirunelveli dist ict, sponsored by the Dharangadhara Chemical Works Ltd., whose requirements will be of the order of 30,000 kW by end of this year.

The structure with 110 kV M.OCBs C.Ts. P. Ts., busbars etc., were supplied by Messrs. ASEA, Sweden through ASEA Electric India Ltd., and erection was done by Departmental engineers. The outdoor switches and insulators were supplied by Messrs. A.E.I. Ltd., Madras. The station Thyrite type lightning arresters manufactured by Messrs General Electric Co., U.S.A., were supplied by Messrs. International General Electric Company. The power and control cables with accessories were supplied by Messrs. A.E.I., Madras, Fraser and Osler, Ltd., Madras, Johnson & Philips Ltd. Bombay, and Philips (India) Ltd., Madras.

The stations is connected to the power line carrier communication grid with interconnections to the various power houses and important substations.

Estimate and Expenditure

The revised estimate for the Pe.iyar Hydro Electric Scheme was sanctioned for a sun of Ruppees 10.99 crores. Out of this, a sum of 3.68 corores is provided for transmission lines and substations which are executed under the control of a Superintending Engineer. It is expected that there will be a saving of about one crore of rupees in the scheme.

Conclusion

This Periyar Power Station opens up the chapter of installation of a new generating station in the Five Year Plan period in Madras State. On this memorable occasion of the inauguration of this first generator, it is befitting to place on record the loyal and selfless work of the staff, labour and contractors, big and small, who have all toiled hard, day and night, relentlessly with a missionary zeal, devotion and single minded purpose of building this edifice and leaving the gift to the nation. It had also been the will of God Almighty that a few, numbering fourteen in all, who had laboured hard together, laid down their valuable lives in the execution of the Project and did not live to see and enjoy the benefits of their hard labour.

Our Contributors

Mr. V. P. Appadurai joined Madras Electricity Department during 1932. He rose to the position of Superintending Engineer of the Technical Branch in 1948 and became Chief Engineer of the Madras Electricity Department in 1954. After the formation of the State Electricity Board in 1957, he is now the Chief Engineer and Technical Member of the Board.

During 1952 he visited U.S.A., Canada, U.K., and the Continent under the Colombo-plan Fellowship Award.

During 1956 he went to Canada as a Member of the Govt. of India Delegation to finalise the terms of Colombo Plan Aid for the Kundah Hydro Electric Scheme. He again went to Canada during 1955 for finalising the orders for plant and machinery required for the Kundah Project, and to Germany during 1958 to expedite the despatch of the generating machinery required for the Periyar Scheme.

S. Muhammad Ali joined the Department during 1936. He went to U.K. during 1946. Now he is the Divisional Engineer in charge of the erection of the generating machinery power transformers and switchgear connected with the Periyar Hydro Scheme.

H. Raghavendra Rao joined the Department during 1939. After serving in various categories he became the Superintending Engineer of the Periyar Hydro Electric Scheme.

S. Subramaniam is a civil Engineer in charge of the Tunnel Works in the Periyar Hydro Electric Scheme.

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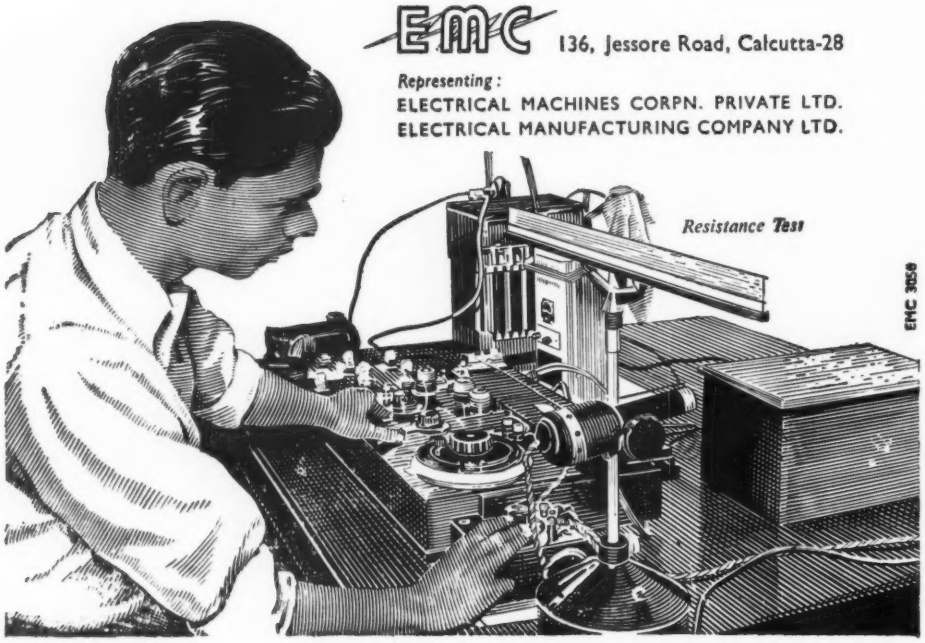

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